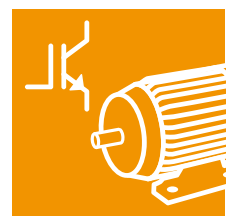


# Training Systems for Drive Technology

Acquiring hands-on, project-oriented  
technical competence





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# Obtaining Technical Skills and Qualifications through Quality Training

## Training systems for drive technology

### Technical progress ...

Drive technology is becoming more and more of a force as automation transforms industry. This field is closely intertwined with other areas of technology like process automation, automatic control technology or computer technology. Due to the rapid pace of developments in this field, drive technology has become one of the most innovative areas of electrical engineering.



### ... is having an enormous impact on training and education

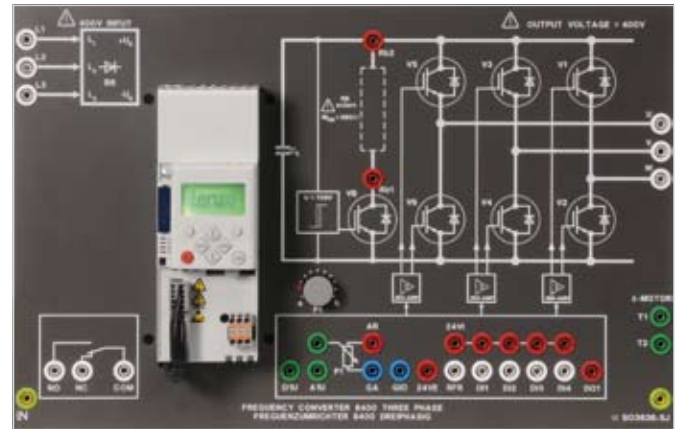
New industrial drive technologies are necessitating new training systems. New developments like the proliferation of frequency converters and servo drives as well as their integration in process automation systems are only a few examples of how fields in vocational studies are being transformed. This increases the demands on today's drive technicians which leads in turn to a need for modern, practice-oriented training systems. Systems that are capable of training students on the latest state-of-the-art technology and how to competently handle such equipment.



## A strong partner in industry ...

... is the guarantee that our systems are closely modelled to actual practice. Lucas-Nuelle has found this strong partner in the highly rated drive technology producer Lenze AG. First, we take the most state-of-the-art drive technology products manufactured by Lenze and modify them for teaching purposes by precisely adapting them to the needs of training schools and educational institutions. All power stages are covered ranging from simple motor controls to frequency converters up to and including servo converters with field-bus interfaces for integration into process automation.

The modularity and scalability of these teaching and training systems form the innovative and cutting-edge foundation for a solid grounding in drive technology.



Source: Lenze AG

# Different Systems for Different Needs

Our objective: to satisfy everyone's expectations

## UniTrain-I – Multimedia Lab with 100 courses

With our UniTrain-I multimedia experiment and training system, the student is guided through theory and well-conceived experiments in clearly structured course software comprising texts, graphics, animations and tests.

In addition to the training software, each course consists of an experiment card on which the practical exercises and operations are carried out. The program offers course instruction on such topics as „electrical machines“, „power electronics“ and „drives“ covering all of the required know-how and skill needed for understanding, connecting, controlling and operating modern drives. Supported by an array of animations as well as numerous experiments on real systems, these courses explore and elaborate on the fundamentals, principles and properties of components found in electrical motors, power electronics and drive systems.



### Your benefits

- Theory and practice at the same time and the same place
- High student motivation induced by PC support and new media
- Rapid learning success thanks to well-structured course design
- Rapid comprehension of theory thanks to animation and graphics
- Technical skills are trained with autonomous experimenting
- Constant feedback provided by comprehension questions and tests
- Guided troubleshooting using integrated fault simulator
- Safety is guaranteed thanks to extra-low safety voltage
- Huge selection of courses (courses on more than 100 topics available)
- Sample solutions for trainers



#### UniTrain-I-System

- Complete, portable lab
- Multimedia courses
- High-tech measurement and control interface
- Theory and practice at the same time



#### UniTrain-I Interface with USB

- Oscilloscope with 2 analog differential inputs
- Sampling rate 40 MSamples
- 9 measurement ranges 100 mV - 50 V
- 22 time ranges 1  $\mu$ s - 10 s
- 16 digital inputs and outputs
- Function generator up to 1 MHz
- 8 relays for fault simulation



#### UniTrain-I Experimenter

- Accommodates experiment cards
- Experimenting voltage  $\pm 15$  V, 400 mA
- Experimenting voltage 5 V, 1 A
- Variable DC or three-phase power source 0 ... 20 V, 1 A
- IrDa interface for multimeter
- Additional serial interface for experiment cards



#### Integrated measuring instruments and power supplies

- Multimeter, ammeter, voltmeter
- 2-channel storage oscilloscope
- Function and waveform generator
- Three-fold power supply for AC and DC
- Three-phase power supply
- ... and much more besides



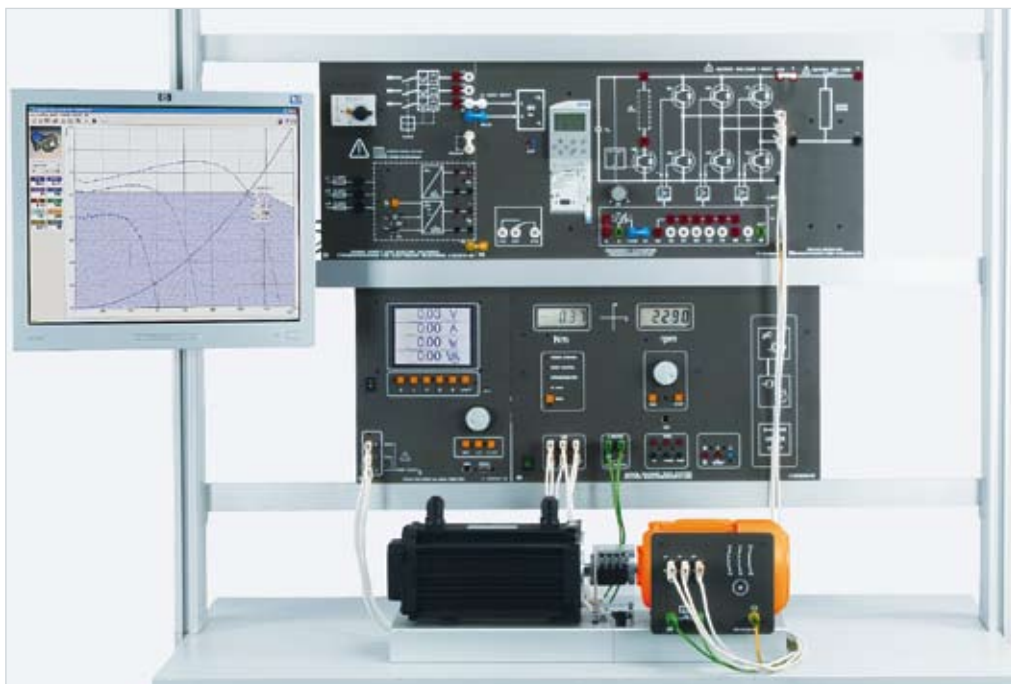
#### Training and experiment software LabSoft

- Huge selection of courses
- Comprehensive theory
- Animations
- Interactive experiments with operating instructions
- Free navigation
- Documentation of the measurement results
- Tests

# Different Systems for Different Needs

## Training panel system

Whether it is for traditional frontal classroom instruction or for hands-on training in student experiments, with the LN training panel system you can implement any kind of instruction or training method. The training panels consist of laminated panels coated with melamine resin on both sides. The panel height is standard DIN A4 so that it can easily be inserted into the experiment stands.



*Training panel system*

### Your benefits

- Multifaceted and flexible thanks to modular design
- Suitable for student exercises and demonstration
- Safe thanks to double insulation (safety sockets and safety cables)
- Integration of industrial components makes systems similar to industrial use
- Clear and legible front panel thanks to contrast-rich and scratch-proof printing process
- Modern instrumentation with PC connection
- Colourful experiment and technical training handbooks
- Student worksheets and sample solutions

## Assembly exercise system

### ... the perfect complement for project-oriented instruction:

In the assembly exercises, emphasis is on the handling of tools and developing manual skill. All of the exercises are of a practical hands-on nature. The electrical connections are carried out with industrial wiring materials (mounting rails, toothed plates, screws etc.) and a variety of wiring methods. All parts and components are reusable except for the consumables (cables).



Assembly exercise system



### Your benefits

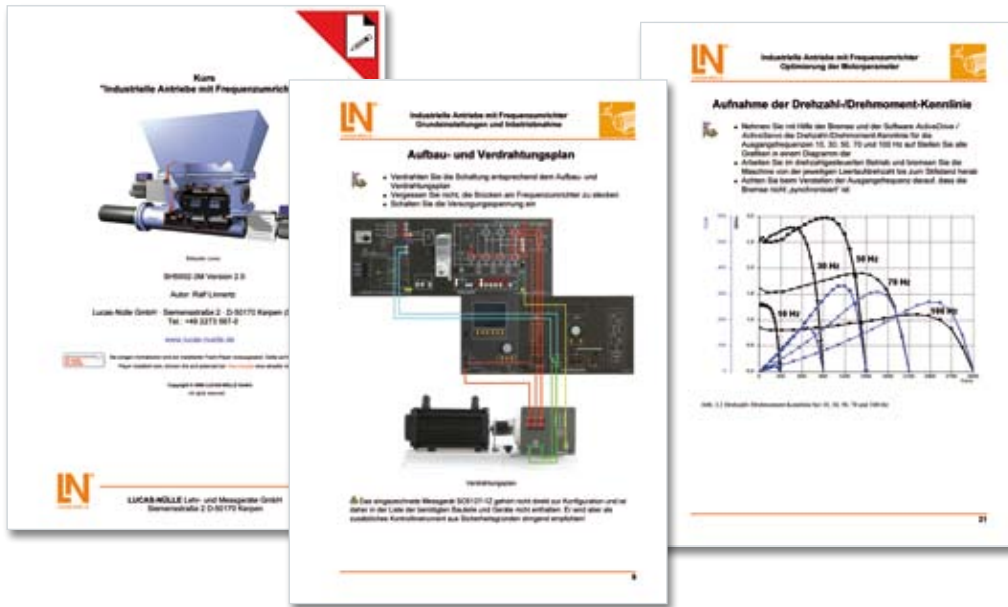
- Plan and implement projects
- Learn connection techniques
- High degree of practical experience using industrial-type technical documentation and software
- Combinable with the LN training panel system
- Circuitry is implemented using industrial components
- Complete project documentation

# Breathing Life into the Presentation of Complex Training Content

## Project-oriented learning media – suitable for all training systems

### Handbooks

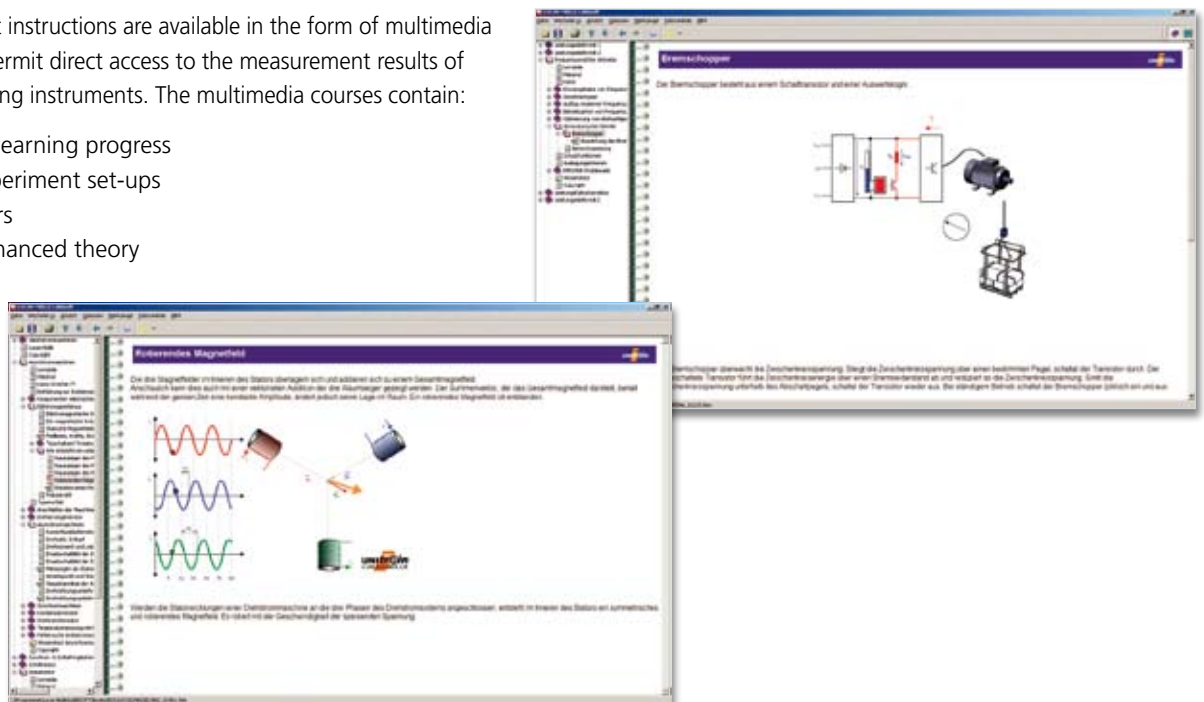
Offering not just detailed descriptions of the training system experiments but also an extensive number of exercises, examples and projects.



### Multimedia courses

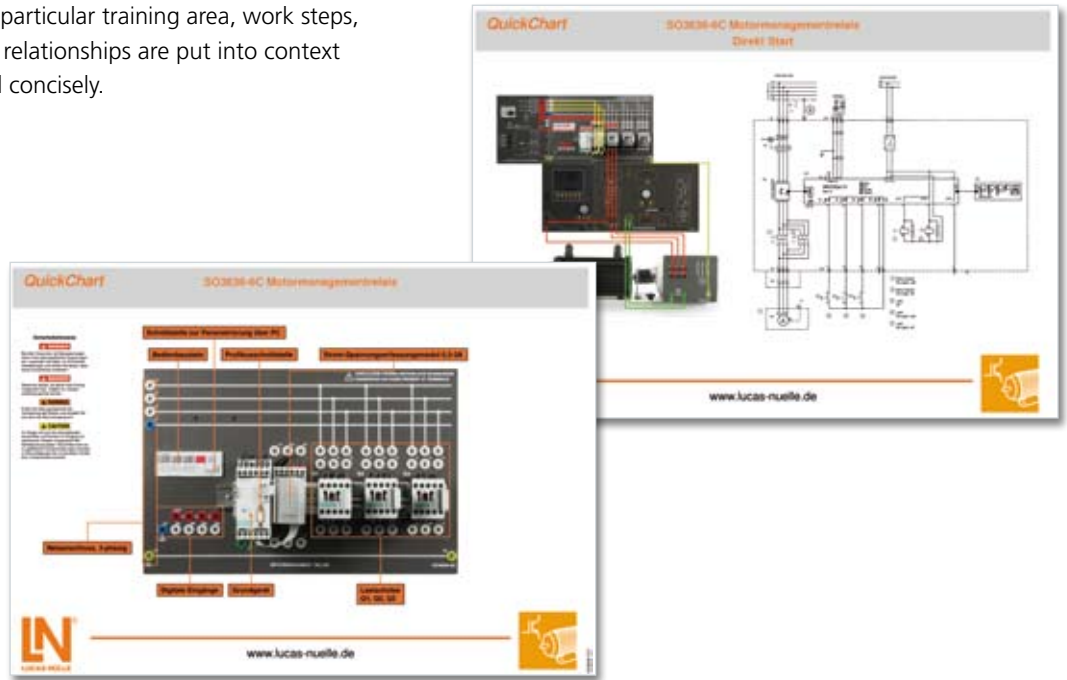
Many experiment instructions are available in the form of multimedia courses. These permit direct access to the measurement results of different measuring instruments. The multimedia courses contain:

- Questions on learning progress
- Interactive experiment set-ups
- Navigation bars
- Animation enhanced theory



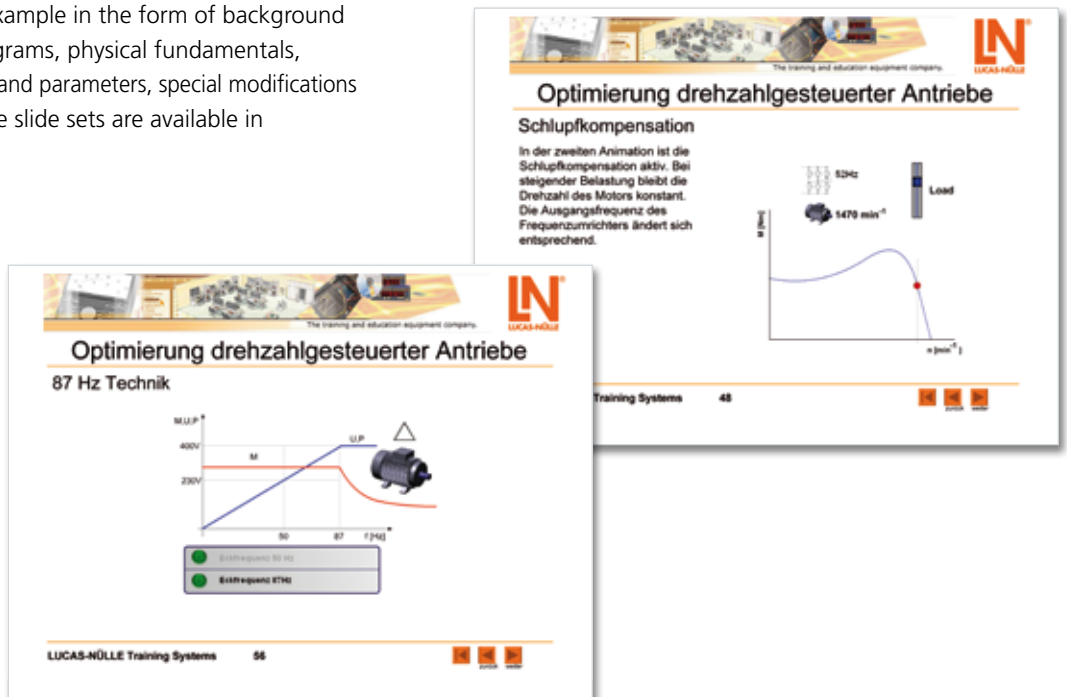
### QuickCharts

Provide a quick overview of a particular training area, work steps, work processes and technical relationships are put into context and elaborated on clearly and concisely.



### Presentation slides

Instructional assistance, for example in the form of background information, block circuit diagrams, physical fundamentals, specific standard specifications and parameters, special modifications and example applications. The slide sets are available in PowerPoint format.



# The Entire Program at a Glance

## Industrial drives

- Putting into operation
- Setting and optimising parameters
- Operating with industrial loads
- Networking with PLC controls
- Project work

## Didactically designed drives

- Operation
- Optimisation
- Operating response

## Power electronics

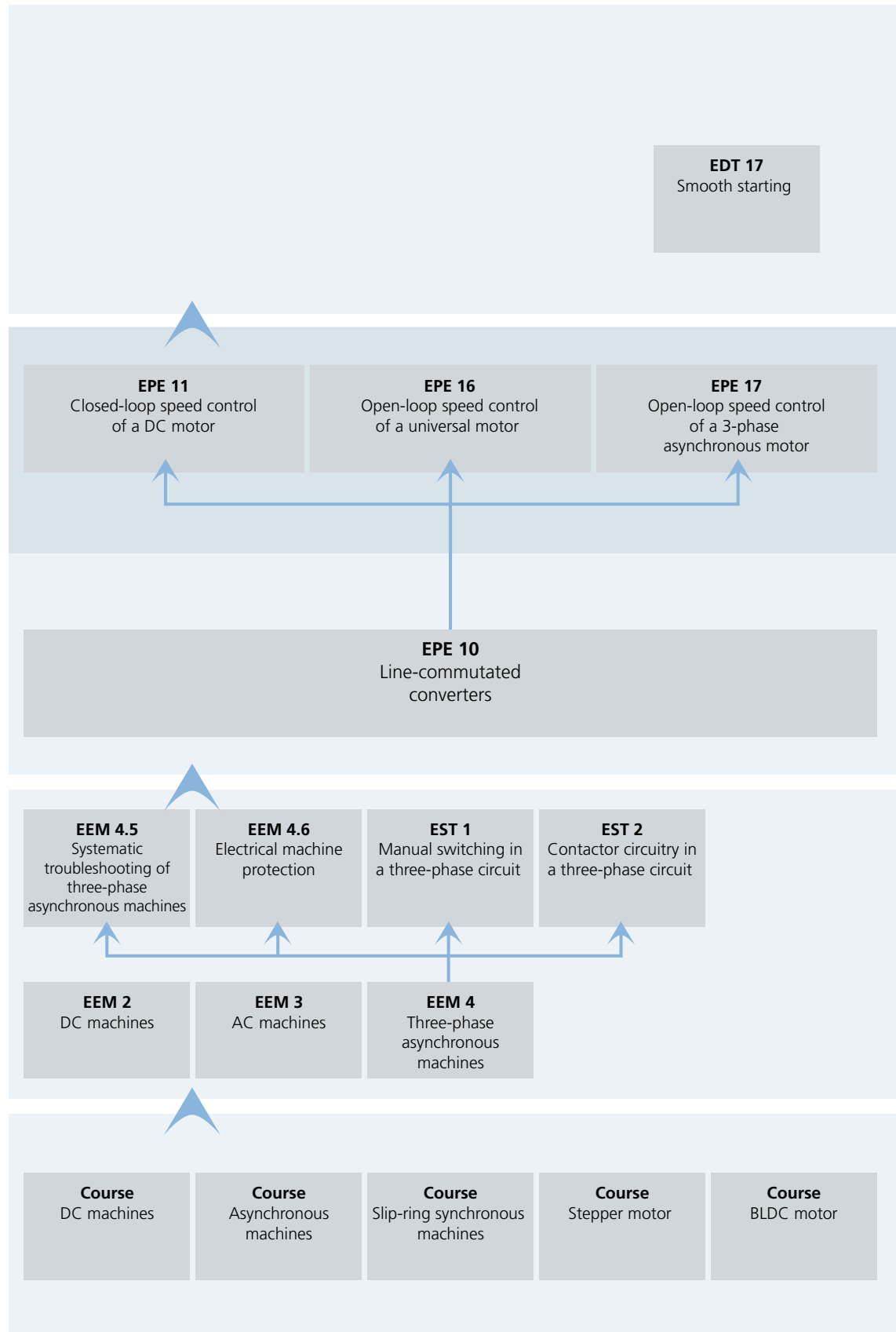
- Circuitry
- Power semiconductors
- Identifying operation and technical context

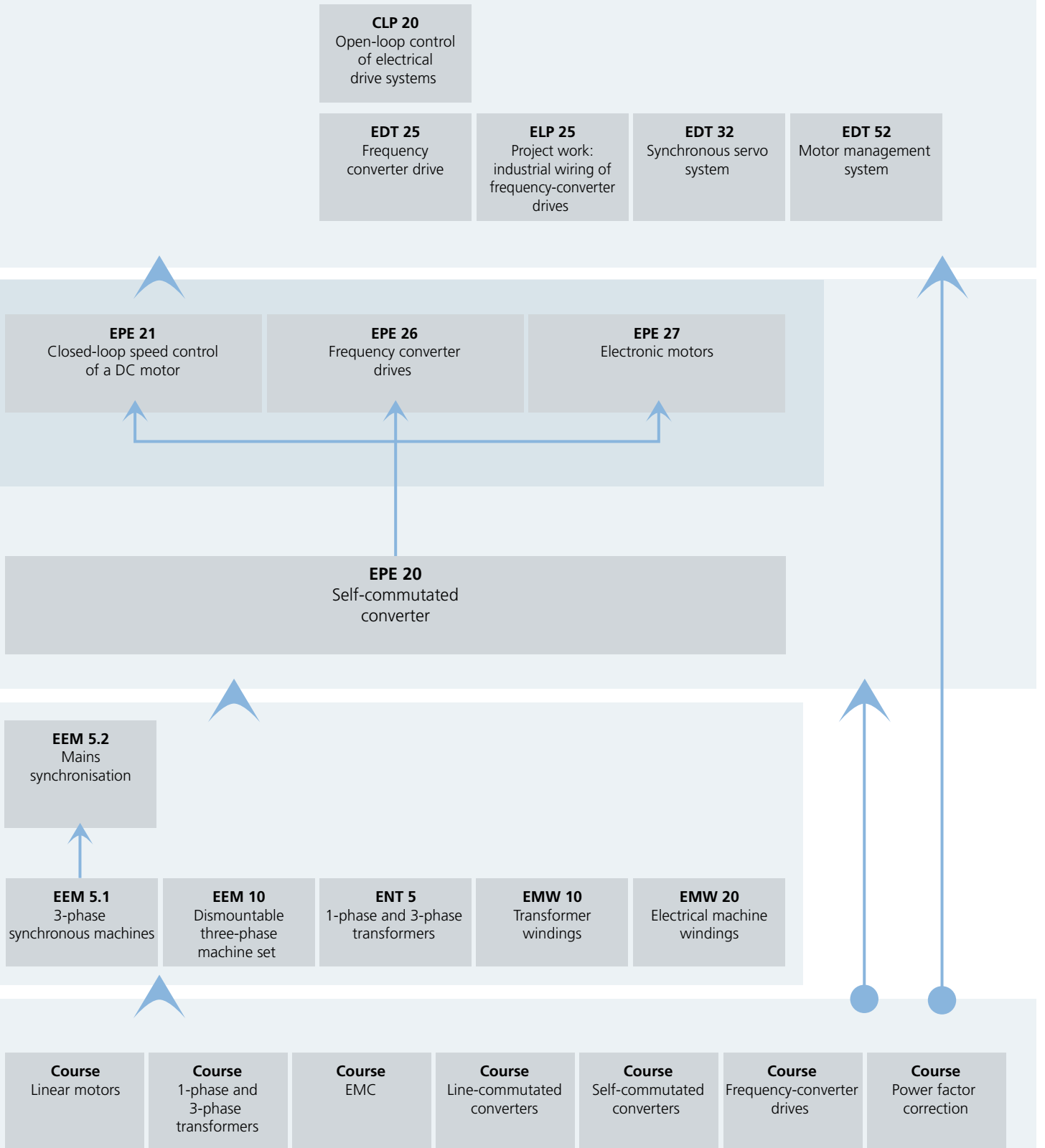
## Electrical machines

- Connection
- Starting
- Motor response
- Measuring speed and torque
- Characteristics
- Project work

## UniTrain-I

- Basic training
- Fundamentals
- Understanding function and operation





# More than a Training System

The full solution laboratory for electrical machines, power electronics and modern drives

Using modern educational media to put life into complex training content

Total solutions for modern drives:  
frequency converters, servo drives, positioning,  
smooth starting, motor management relays



**Connection, starting and testing of DC, AC, three-phase and synchronous machines**

**Blended learning:  
multimedia-based instruction  
using UniTrain-I**

# One Drive Program, Two Power Classes

## 300 W and 1 kW

The complexity inherent in industrial drive technology poses a special challenge for the training and education of electronics and mechatronics specialists. Understanding and mastering electrical machines, their construction design, their operation, connection techniques, characteristics and especially their operating response in conjunction with different loads; all of this constitutes the core competencies of skilled workers, technicians and engineers. To live up to the various requirements in this field, Lucas-Nülle offers drives in two different power classes – 300 W and 1 kW.



## Two power classes – targeting two different user groups

### Benefits

- Record typical machine characteristics
- Response equivalent to that of machines of considerably higher power classes
- 300 W – standard equipment for drive technology and mechatronics
- 1 kW – high-end equipment set for drive technology, mechatronics and power engineering



## Safe operation and handling

All connections are carried out using safety connecting cables and sockets.

### Benefits

- Highly safe circuitry
- Clearly labelled connections and terminals
- Labelling corresponding to DIN/IEC standards
- All moving parts are protected with safety guards
- Temperature sensors protect the machine against thermal overload



## Optimum handling

All machines of the same power class are outfitted with shafts of the same height and come with a vibration-attenuating base frame.

### Benefits

- Permits simple, stable coupling of machines and attachments
- Tightly fitting, elastic coupling sleeves
- High-traction and disturbance-free operation



# Two Machine Test Stands

## Complete and all-encompassing – servo machine test stand

The servo machine test stand is a complete testing system designed for the investigation of electrical machines and drives. It consists of the digital control unit, a servo drive and the ActiveServo software. The system combines the latest technology with simple, easy-to-use handling. Besides the drive and brakes, it is also possible to realistically emulate working machine models. This is how machines, generators and drives can be studied in the laboratory under industrial conditions. The system contains 10 different operating modes/working machine models. There is a system specially adapted for both power classes.



### Control unit

- Drives and brakes operate 4 quadrants
- Dynamic and static operating modes
- USB interface
- Determining speed and torque
- Integrated electrically isolated measurement amplifier for current and voltage measurement
- Thermal monitoring of machine under test
- Safety disabling when operated without shaft guard



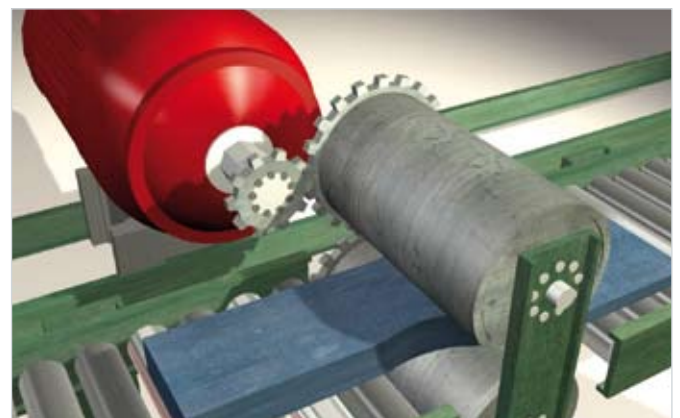
### Drive unit

- Self-cooling servo
- Integrated speed and rotor position detection using a resolver
- Temperature monitoring with built-in temperature sensor
- System is drift-free and calibration-free
- Connection utilises plug-in connector protected against polarity reversal
- High power reserves for detailed and precise emulation of loads



### 10 operating modes

- Automatic torque control
- Automatic speed control
- Manual and automatic mains synchronisation
- Flywheel drive
- Lift drive
- Roller/calendar
- Ventilator
- Compressor
- Winding drive
- Freely definable time-dependent load



For software see page 22/23

# Two Machine Test Stands

## Functional and compact – the active machine test stand

The active machine test stand combines a drive and brake unit in a single device. Besides recording machine characteristics, you can also investigate drives with different working machine models. Thanks to the ActiveDrive software included within the scope of delivery, all of the various functions can be controlled via the PC. The active machine test stand makes it possible to carry out all of the critical experiments in the 300-W power class.



### Control unit

- 4-quadrant operating mode
- Integrated electrically-isolated measurement amplifier for current and voltage measurement
- USB interface
- Determines speed and torque
- Thermal monitoring of machine under test
- Safety disabling when operated without shaft guard



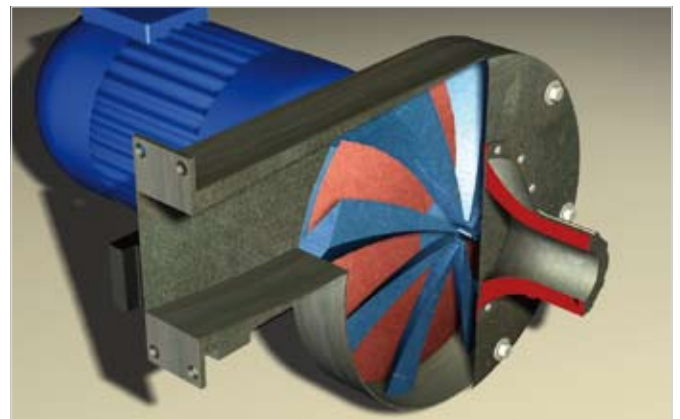
### Drive unit

- Self-cooling asynchronous motors
- Integrated speed and rotor position detection using an integrated incremental sensor
- System is drift-free and calibration-free
- Connection utilising plug-in connector protected against polarity reversal



### 5 operating modes

- Automatic torque control
- Automatic speed control
- Lift drive
- Roller/calander
- Ventilator



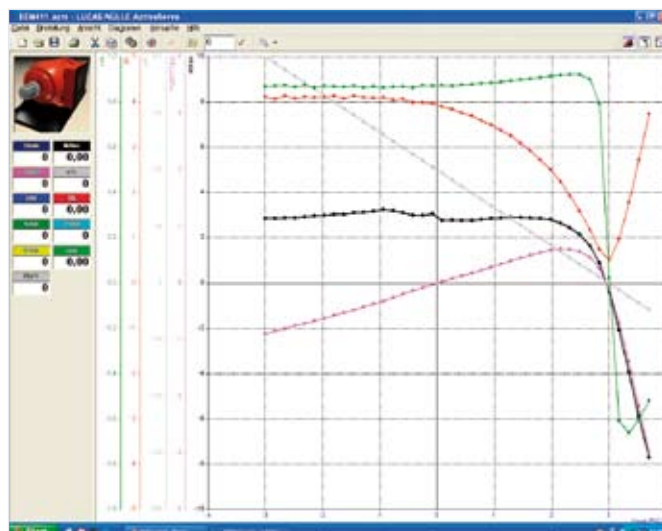
For software see page 22/23

# Perfect Support – PC Operation and Measurement Value Recording

... doing what ActiveServo and ActiveDrive were designed for.

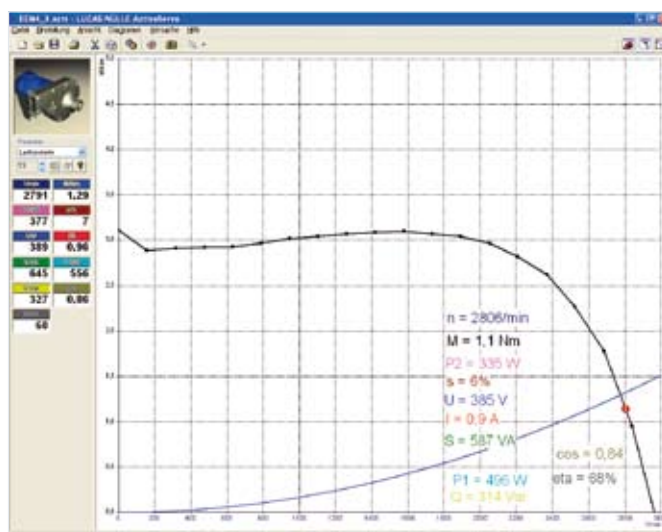
## Recording motor characteristics

- Measurement across all four quadrants
- Recording measured values in speed and torque controlled operation
- Measurement, calculation and graphic display of measured and calculated mechanical and electrical variables
- Freely definable ramp functions for performing PC controlled load experiments



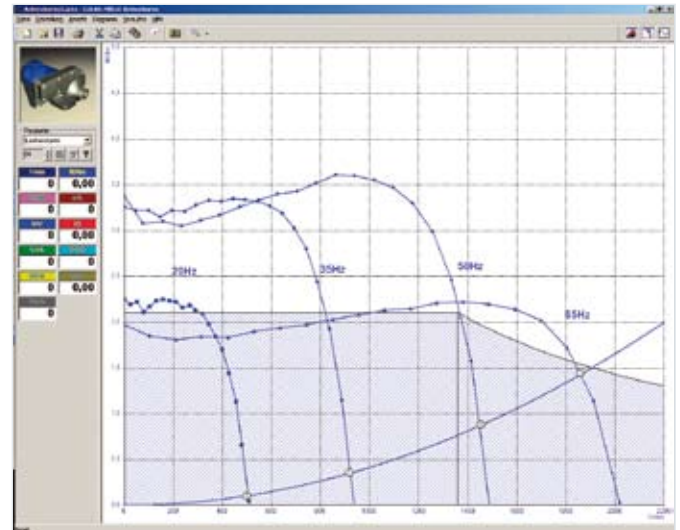
## Determining operating point with adjustable, emulated working machines

- Superpositioning of curves from drive and working machines
- Realistic and precisely detailed emulation
- Determination of stable and unstable operating points
- Determination of the working and overload range



### Integrated evaluation of measurement results

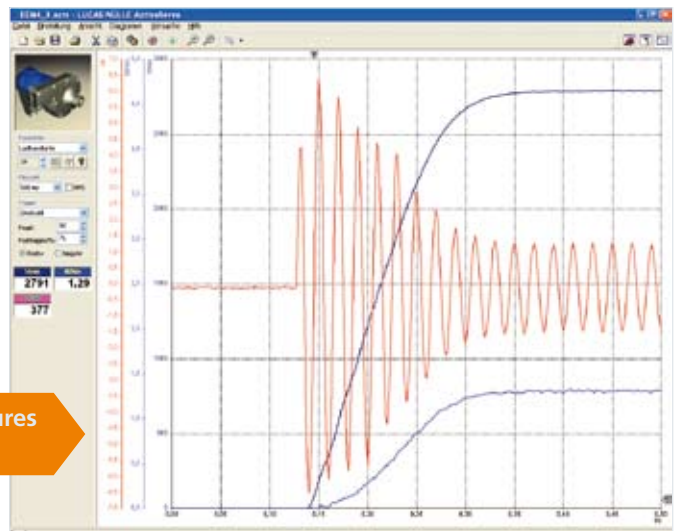
- Simultaneous display of the characteristics of different measurement sequences to illustrate changes (here, changes to parameters on a frequency converter)
- Plotting permissible operating range and the nominal values in a graph
- Labelling measurements in a graph
- Comfortable export of measurements into a spreadsheet program for further processing



### Dynamic measurements in the time domain using the servo machine test stand

- Determination of starting currents under different loads
- Dynamic examination of controlled drives
- Realistic emulation of working machines even under dynamic conditions
- Depicts electrical variables as momentary values or as rms values

Additional features  
of ActiveServo



# Analog/Digital Multimeter

## Four different meters in one instrument

The areas of electrical machines, power electronics and drive technology place particular demands on measuring instruments. Besides very high overload protection, the registering of the measured values must be carried out independently of the recording of the curve. The analog/digital multimeter was designed especially for this. It simultaneously replaces up to four different measuring instruments – being an ammeter/voltmeter, power meter and phase angle meter all in one. The graphic display allows the instrument to be used both for student experiments as well as for demonstration purposes.



## Equipment

- Simultaneous measurement of both voltage and current independent of the curve shape (measurement of clocked voltages)
- Calculation of active, apparent and reactive power and power factor
- Electrically damage-proof up to 20 A/600 V
- Large, contrast-rich background illuminated graphic display
- Large or standard display of up to 4 measured values



## PC connection

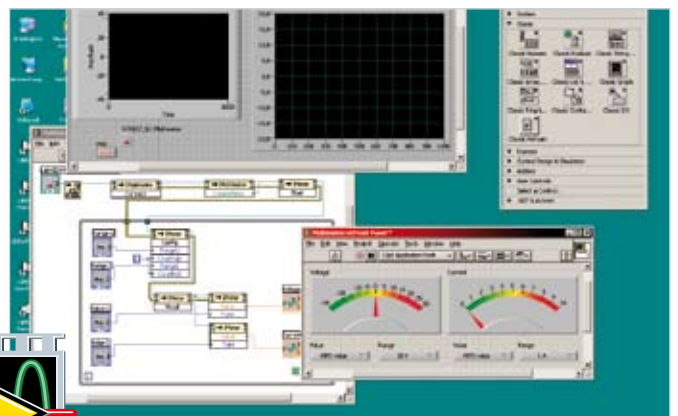
Using the USB interface, all of the measured values can be displayed on the PC. The following instruments are available:

- Voltmeter, ammeter, power indicator
- Power phasor for motor and generator operating modes
- Oscilloscope for the display of current, voltage and power
- Data logger for recording the values of up to 14 different measurement variables



## LabVIEW compatible

LabVIEW drivers as well as various functional examples permit analog and digital multimeters to be integrated into the LabVIEW environment.



# Electrical Machines

## The foundation for drive technology

Electrical machines form the very basis of modern drives. New training and educational priorities have necessitated new training qualifications for the commissioning and operation of electrical machines. One area of particular importance is the operation of various working machines such as ventilators, lifting equipment and flywheels. The fundamentals of electrical machines are graphically presented using many examples, explanatory texts, exercises and practical assignments.



### Multidisciplinary nature

Electrical machines are a central component of modern processing systems, plants and equipment. They are deployed in such areas as mechanical engineering, conveyor and transport technology, process engineering and production lines. Processes continue to become more and more automated through modern power electronic controls and the use of programmable logic controls.



### Practice-oriented deployment

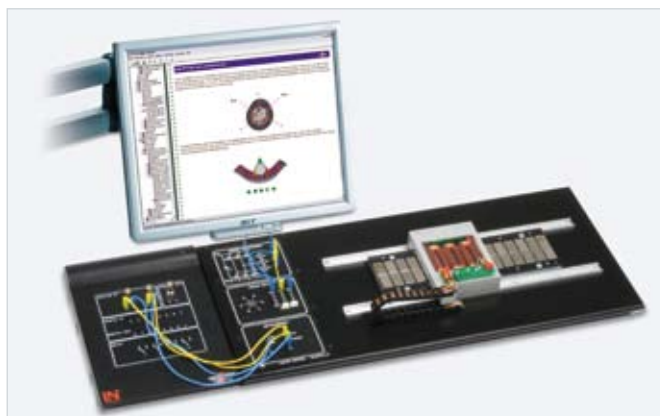
Using the “Electrical Machines” training panel system, students explore the practical side of connecting up and operating electrical machines. The accumulated experience is then made more concrete by means of a host of practical exercises and projects.



### Training systems

The training systems are designed to convey the basic knowledge of electrical machines, demonstrating how they work and displaying their characteristics. The fundamentals of electrical machines are graphically presented using many examples, explanations, exercises and practical assignments.

- UniTrain-I “Electrical Machines”
- Training panel system “Electrical Machines”



# DC Machines

## Shunt-wound machine – series-wound machine – compound-wound machine – universal machine

The DC machine continues to serve as an introduction to the entire field. In actual industrial applications, these motors nowadays tend only to be deployed as small drives with permanent excitation.



**UniTrain**  
SYSTEM

### Training content

- Shunt-wound, series-wound, compound-wound, universal machine
- Connection of DC machines
- Initiating experiments on starting
- Setting the neutral zone
- Investigating operating response under field-weakening conditions
- Familiarisation with open-loop speed control
- Carrying out experiments on generator and braking operation

# Asynchronous Machines

Squirrel-cage motors – permanent magnet motors – capacitor motors – short-circuit rotors – voltage regulating transformers

Thanks to their enormous popularity, asynchronous machines are of supreme importance – all the more so in training and education.



**UniTrain**  
SYSTEM

## Training content

- How static and rotating magnetic fields arise
- Stator voltage and current measurements on the stator
- Connection of the stator in star or delta circuit configuration
- Different operating responses for different rotors
- Different response for start-up as well as in the field-weakening range
- Troubleshooting

# Synchronous Machines

## Slip-ring rotor machine – synchronous machine – reluctance machine

Synchronous machines are primarily used as generators in power generation and as highly dynamic drives (servos).



**UniTrain**  
SYSTEM

### Training content

- Explaining through actual practice how the technology works including its applications
- Exploring the physics needed to understand the technology
- Starting machines with starting resistors and at variable frequency
- Open-loop speed control
- Influence of open and connected rotor windings
- Effects of different exciter voltages

# Stepper Motors

## Design – operating principle – positioning

Stepper motors allow for a cost-effective solution to your positioning needs. For that reason they are produced in large volumes for a variety of industrial applications.



**UniTrain**  
SYSTEM

### Training content

- Illustrate stepper motor technology using animations, theory and experiments
- Control operation principles
- Demonstrate differences between two current-limiting methods
- Limits of the stepper motor
- Complex positioning assignments

# Servo/BLDC Motors

## Operation – position detection – closed-loop control

Brushless DC motors (BLDC) are being used in the most diverse areas and applications. BLDC motors have a high degree of efficiency and operate like permanently excited synchronous motors.



**UniTrain**  
SYSTEM

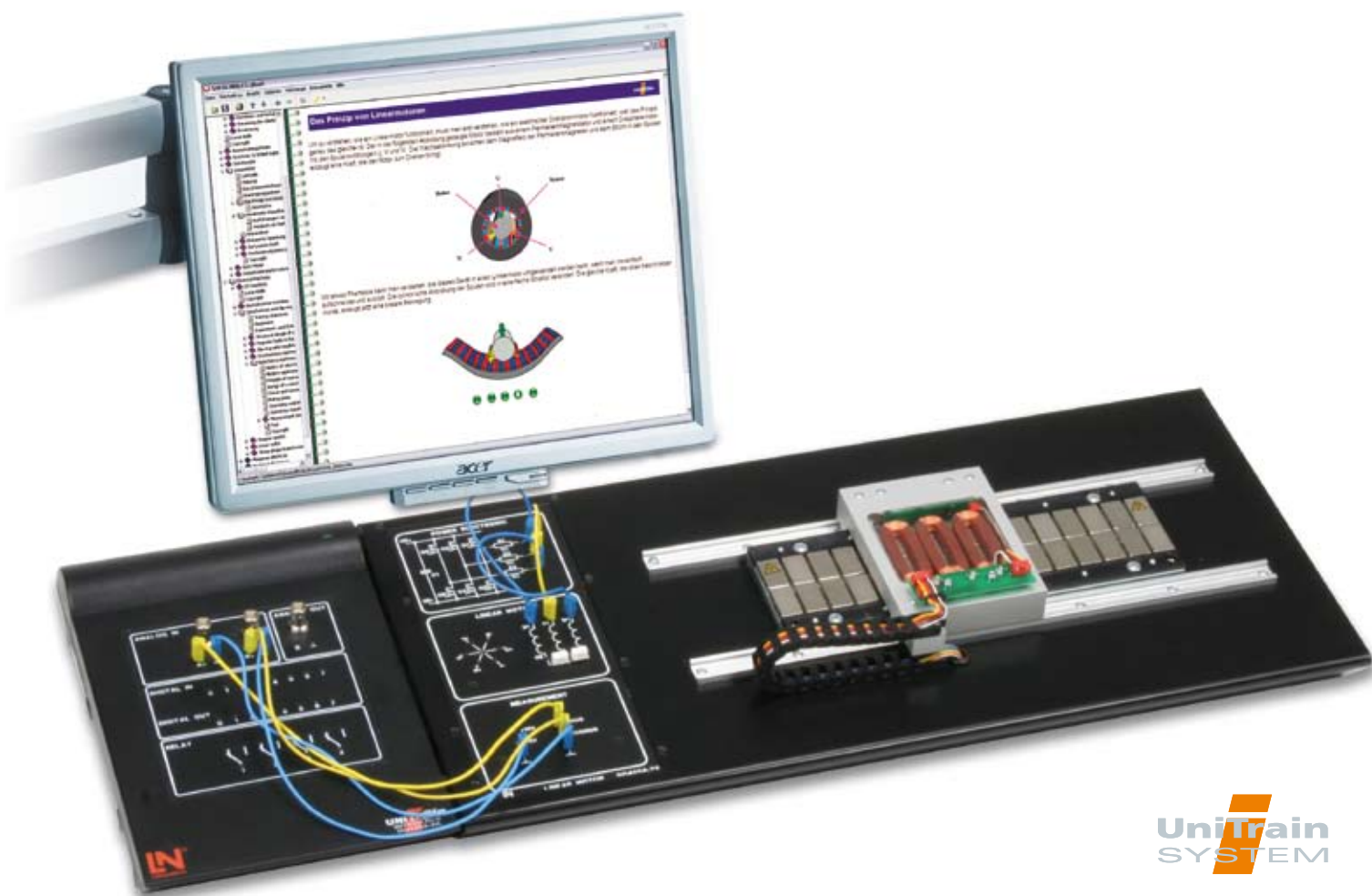
### Training content

- Design and operation of the motor and the control electronics
- Examining the pick-up system
- Investigating the power supply of the motor
- Design of a torque- and speed-controlled drive

# Linear Motors

## Operation – applications – positioning tasks

Linear motors are very effective in just about any application requiring linear motion. Even in modern automation applications there is no way to get around linear motors.



**UniTrain**  
SYSTEM

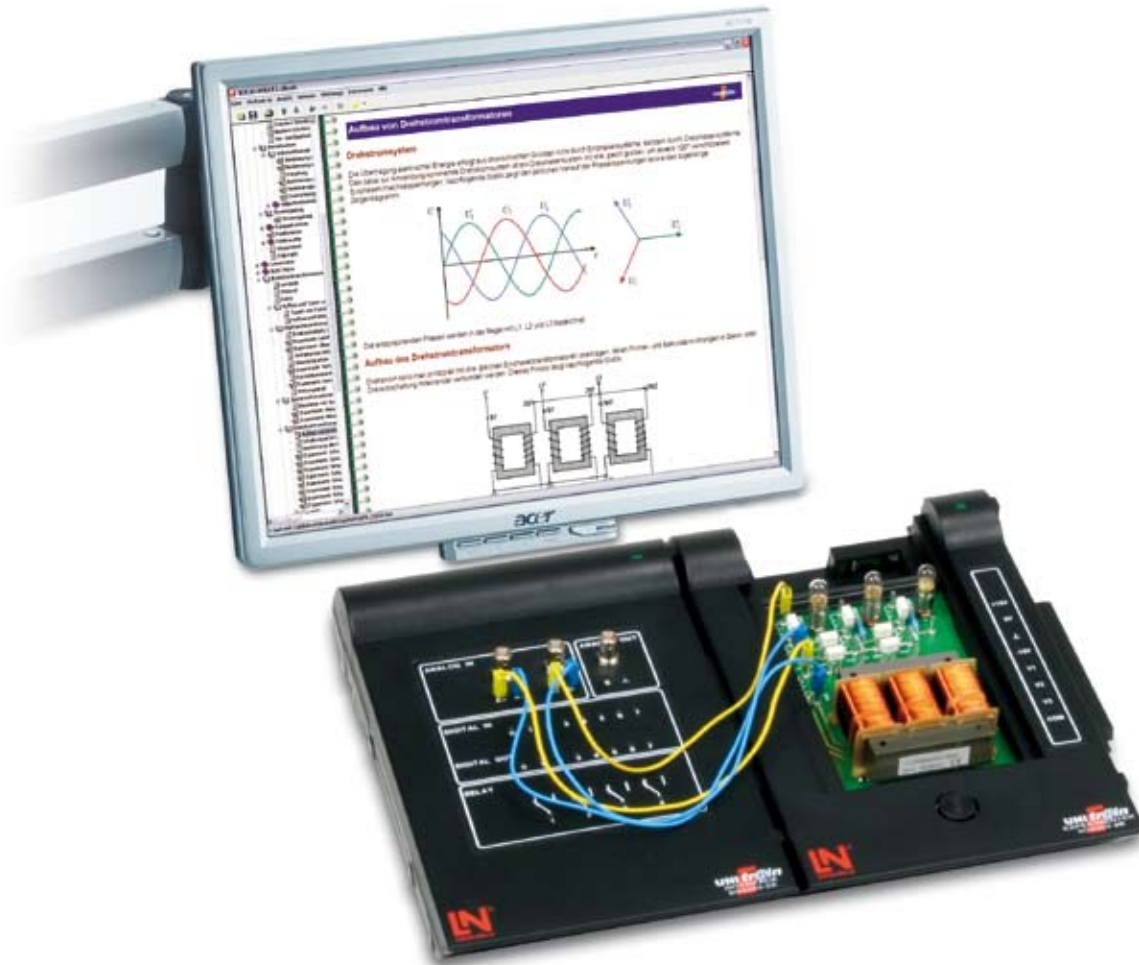
### Training content

- Design, operation and operating responses of linear motors
- Meaning of the terms „Lorentz force“ and „induced voltage“
- Applications for linear motors
- Different designs of linear motors
- Determining the motor constants
- Positioning operations with the linear motor
- Methods of detecting position (encoder, Hall-type sensors)
- Determining position with the aid of analog Hall sensors

# Three-phase Transformer

## Design – connection types – load response

Transformers are electrical machines designed to convert alternating or three-phase currents into higher or lower voltages. Three-phase transformers are particularly important in transmitting electrical power.



**UniTrain**  
SYSTEM

### Training content

- Become familiar with the transformer principle and the equivalent circuit diagram
- Investigate load response of 1st- and 4th-quadrant operating modes
- Record current and voltage with and without load
- Investigate the transmission ratio
- Investigate how various loads respond to various vector groups
- Investigate asymmetrical loads connected to different vector groups
- Determine short-circuit voltage

# Electromagnetic Compatibility

## Coupling effect – interference immunity – standards

Aspects of a circuit's electromagnetic compatibility play an important role during development and fault finding. Here, coupling effects within the circuit as well as interference are of importance.



**UniTrain**  
SYSTEM

### Training content

- The meaning of the term “electromagnetic compatibility” (EMC)
- Describing electromagnetic coupling effects
- Investigation of galvanic, inductive and capacitive coupling between conductor paths
- Measures taken to improve a circuit's EMC properties
- Measures taken to enhance a circuit's immunity to interference

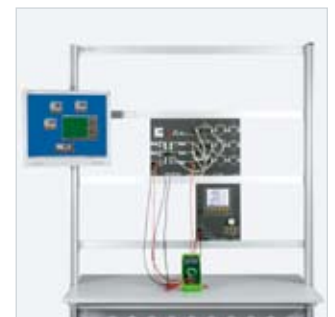
# Transformer Windings

## Assembling single-phase and three-phase transformers

The manufacture of transformers is at the core of this training system. Everything about transformers is learned in the course of hands-on assembly and operation. The training system contains all of the components and tools needed to manufacture transformers. And most of these components are recyclable, so once you've completed the experiment, you can disassemble the transformer again. Additional experiments enable you to investigate the transformer's operating response in conjunction with different loads.



Experiment example: "Windings of transformers EMW 10"



Wound transformers under test

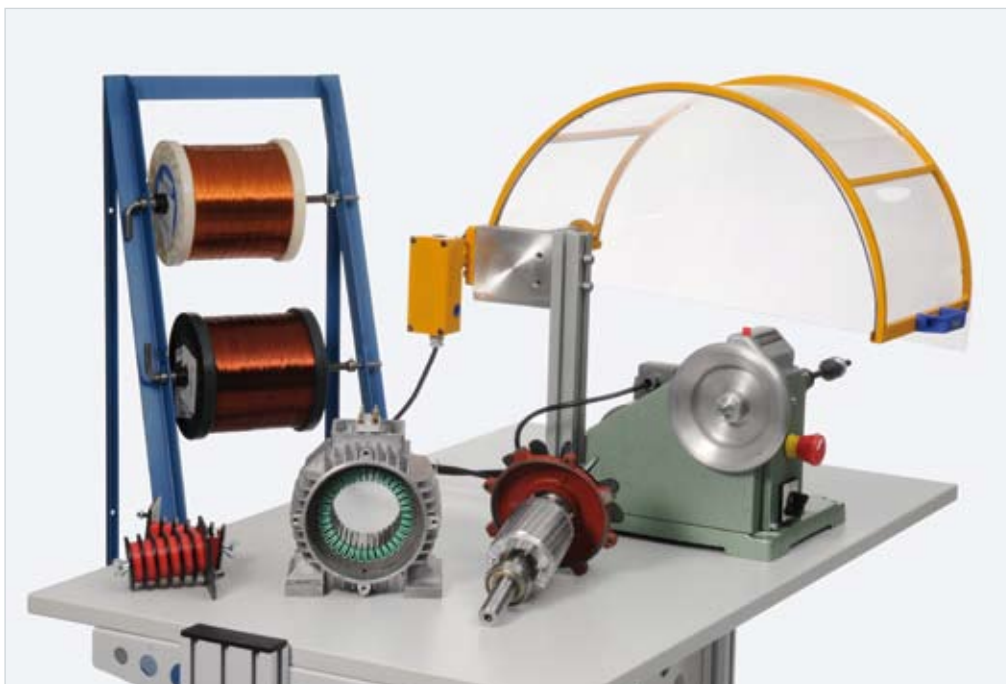
### Training content

- Design and operation of single-phase and three-phase transformers
- Calculating winding data
- Producing windings
- Testing transformer operation according to standards
- Investigating different operating responses under different loads and vector groups

# The Windings of Electrical Machines

## Assembly of a three-phase motor with squirrel-cage rotor

The training system provides instruction on the coil windings of a three-phase motor with squirrel-cage rotor. In the process windings are wound into a coil and the coil is inserted into the stator and connected up. A completely functional motor is assembled. This allows the design and operation of a motor to be learned through actual hands-on practice. The training system contains all of the components and tools required for the manufacture of a three-phase asynchronous motor. Most of the components can be reused after the experiment has been performed. In additional experiments, the various operating modes are investigated using the machine-testing stand.



Experiment example: "Coiling the winding of the three-phase asynchronous motor with squirrel-cage EMW 20"



Wound motor under test

### Training content

- Electrical and mechanical design motors
- Determining the winding data
- Producing windings
- Inserting and wiring coil windings
- Testing motor operation according to standard
- Connection, wiring and putting into operation
- Recording the speed and torque response

# DC Machines

## Shunt-wound machine – series-wound machine – compound-wound machine

DC machines continue to form the foundation for training in the area of electrical machines. They are used to clearly and concisely demonstrate the potential of open-loop and closed-loop control techniques.



Experiment example: "DC machines EEM 2"

### Training content

#### Motor operation:

- Motor connection
- Comparing various machine types
- Typical machine ratings and characteristics
- Speed control with starter and field regulator
- Reversing rotation direction

#### Generator operation:

- Generator connection
- Armature voltage as a function of exciter current
- Function and use of the field regulator
- Self-excited and separately-excited voltage control
- Load diagrams of the generator

# AC Machines

## Universal motors

Universal motors are static converter machines and principally serve as drives for electric tools and household appliances. They are found with power ratings of up to around 2 kW. Thanks to their simple speed control, universal motors make up a considerable percentage of all AC machines.



Experiment example: "Universal motor EEM 3.1"

### Training content

- Connection, wiring and putting into operation
- Reversal of rotation direction
- AC- and DC-voltage operation
- Recording the speed and torque response
- Operation with different load machines such as ventilators

# AC Machines

## Single-phase motor with bifilar starter winding

The single-phase motor with bifilar starter winding is one of the asynchronous machines. In addition to the main winding there is a starter winding which has a high internal resistance which is partially bifilar and thus magnetically ineffective. This is disconnected after starting is achieved. The motors do not contain any parts which would be subject to wear and tear like a collector or slip-rings, and it operates at a fixed, virtually synchronous speed. The power range reaches up to approx. 2 kW.



Versuchsbeispiel "Einphasenmotor mit Bifilar-Anlaufwicklung EEM 3.3"

### Training content

- Connecting, wiring and putting into operation
- Reversal of rotation direction
- Recording the speed and torque responses
- Operation with different load machines, like ventilators

## Single-phase motor with operating and starting capacitor

Single-phase motors with operating and starting capacitors belong to the cadre of asynchronous machines. Besides the main winding, these motors are equipped with an auxiliary winding with a series connected capacitor. The motors do not contain any components which are subject to wear and tear like collectors and slip-rings and operate at a fixed and virtually synchronous rotation speed. The power range reaches up to approximately 2 kW. Capacitor motors are used to drive household appliances, refrigerators as well as small-scale drives used in manufacturing machinery.



Experiment example: "Single-phase motor with operating and auxiliary capacitor EEM 3.4"

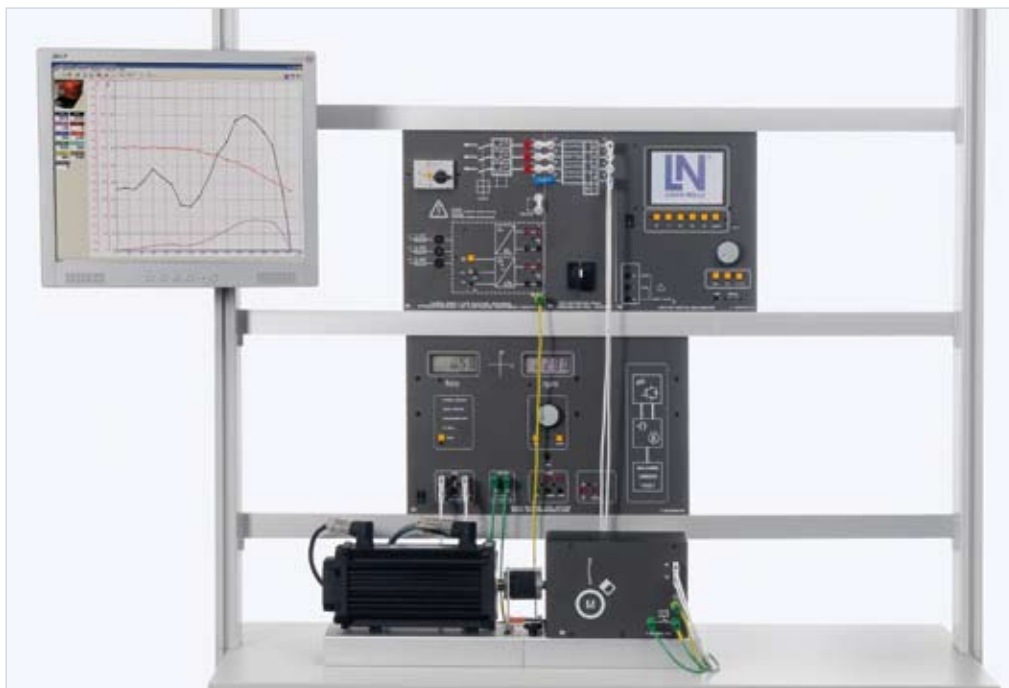
### Training content

- Connecting, wiring and putting into operation
- Reversing the rotation direction
- Operating with and without starting capacitor
- Recording the speed and torque response
- Start-up and starting capacitor
- Investigating the current relay

# AC Machines

## Split-pole motors

Split-pole motors excel due to the fact that they are cost-efficient to produce and practically maintenance-free. Split-pole motors are constructed especially for deployment in mass produced devices like ventilator motors or discharge pumps. The power range stretches from a few watts up to a power level of approx. 150 W.



Experiment example: "Split-pole motor EEM 3.5"

### Training content

- Connecting, wiring and putting into operation
- Recording the speed and torque characteristics
- Operating with different load machines such as ventilators

# Three-phase Asynchronous Machines

## Three-phase motors with squirrel-cage rotor

Three-phase motors with squirrel-cage rotors are the most frequently used motors in industry. These motors are not only both robust as well as maintenance-free but are inexpensive to produce. These motors can be found in low power versions in the watt ranges up to and including power levels of several megawatts. Thanks to the use of modern frequency converters, these motors can operate virtually loss-free at varied speeds so that ever more application areas are being found for them.



Experiment example: "Three-phase motor with squirrel-cage rotor EEM 4.1"

### Training content

- Connecting, wiring and putting into operation
- Operation in star and delta connection configuration
- Deployment of a star-delta switch
- Recording speed and torque characteristics
- Operation with various load machines such as ventilators, hoisting machinery

# Three-phase Asynchronous Machines

## Pole-switchable three-phase motor according to Dahlander

Due to the special winding the three-phase motor with Dahlander circuit enables the three-phase motor to be operated at two different speeds. The ratio of the speeds for this circuit is 2:1. With this type of motor simple drives can be assembled that are capable of two speeds, for example, a two-staged ventilator drive.



Experiment example: "three-phase pole-switchable motor according to Dahlander EEM 4.2"

### Training content

- Connecting, wiring and putting into operation
- Operation with high and low speed stages
- Using a pole reversing switch
- Recording speed and torque characteristics
- Operation with different load machines such as ventilators, hoisting equipment

## Three-phase pole-changing motor – two separate windings

The system consists of two three-phase motors in a single housing with separate windings. Since both windings operate separately from each other different integer ratios can be produced between the speeds. These motors are always used for simple applications wherever the speed ratio between slower and faster speed is greater than two, for example, in crane applications where you have inching mode and higher speed.



Experiment example: "Three-phase pole-switchable motor with two separate windings EEM 4.3"

### Training content

- Connecting, wiring and putting into operation
- Operation at higher and lower rotation speeds
- Using a pole reversing switch
- Recording the speed and torque characteristics
- Operation with different load machines such as ventilators, hoisting equipment

# Three-phase Asynchronous Machines

## Three-phase motor with slip-rings

In contrast to motors with squirrel-cages, slip-ring motors are equipped with a rotor outfitted with wound coils. These rotors can be connected to resistors or static converters. This makes speed adjustment possible.



Experiment example: "Three-phase motor with slip-rings EEM 4.4"

### Training content

- Connecting, wiring and putting into operation
- Adjusting the speed by altering resistance across the rotor
- Recording the speed and torque characteristics
- Operation with various load machines such as ventilators, hoisting equipment

## Systematic trouble-shooting on a three-phase asynchronous machine

Simply plug the fault simulator into a three-phase asynchronous motor. The widest range of realistic faults can be activated using lockable fault switches. These faults can be detected and analysed using industrial-type measuring instruments. Repair measures can be worked out on the basis of the measuring results. All measurements are performed with the power switched off.



Open fault simulator

Experiment example: "Protection of electrical machines EEM 4.5"

### Training content

- Winding breaks in coils
- Winding-to-winding insulation faults
- Winding-to-housing insulation faults
- Combination of various faults
- Fault assessment and practical repair measures
- How to handle insulation meters

# Three-phase Asynchronous Machines

## Protection of electrical machines

Squirrel-cage motors were designed to operate with constant loads. Load changes as well as high start-up currents lead to impermissible overheating of the motor. Sensors are used to monitor the temperature and the motor's current consumption. These activate protective devices such as motor circuit-breakers, protective relays or thermistor relays.



Experiment example: "Protection of electrical machines EEM 4.6"

### Training content

- Selection, installation and adjustment of various motor protection systems
- Motor circuit-breaker
- Motor protection relay
- Thermistor protection
- Influence of various operating modes on the heat build-up of the motor
- Tripping characteristics of the protective systems
- Protection against impermissible operating states

## Manually-operated switching in the three-phase circuit

The development of circuits as well as the correct choice of circuit elements and equipment is at the focal point of this training system segment. Multi-poled motors up to a certain power class can be switched directly into the three-phase circuit. To do this there is the appropriate switching equipment for each application.



Experiment example: "Manually-operated switching in the three-phase circuit EST 1"

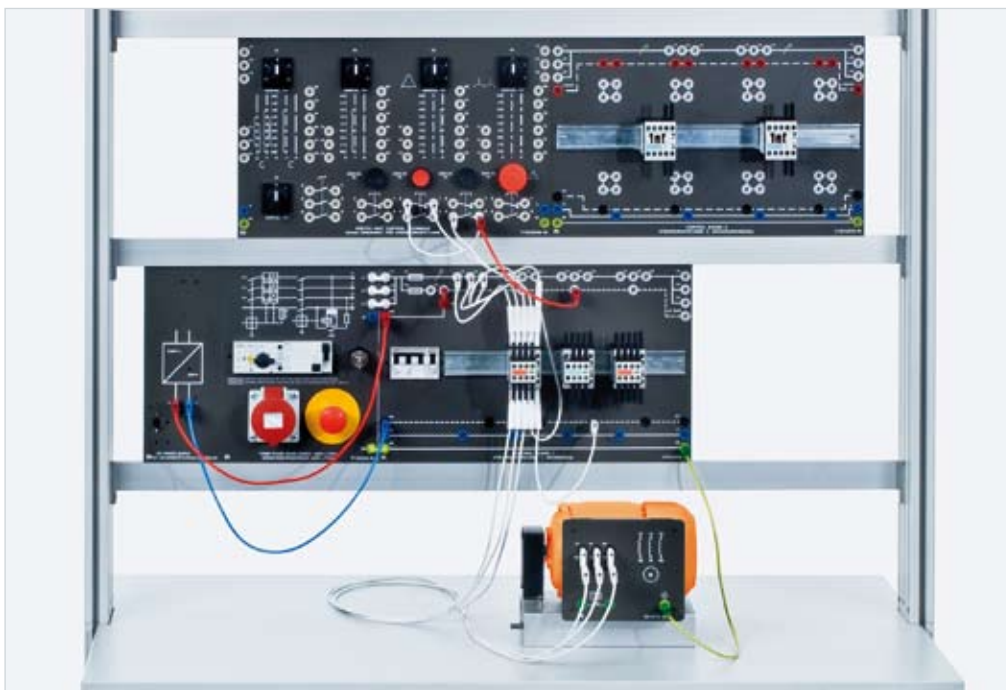
### Training content

- Manual switching in the three-phase circuit
- Contactor circuitry in the three-phase circuit
- Compact programmable control
- Switch-off of a three-phase induction motor with squirrel-cage rotor
- Star-delta circuit of a three-phase induction motor with squirrel-cage rotor
- Star-delta reversing circuit of a three-phase induction motor with squirrel-cage rotor
- Pole reversing with three-phase induction motor according to Dahlander
- Pole reversing with three-phase induction motor with two separate windings

# Three-phase Asynchronous Machines

## Contactor circuits in a three-phase circuit

Starting at a certain power class, it is no longer possible to switch three-phase machines directly. This is why indirect switching is performed on these machines using contactor circuits of various kinds. The training here features the development of control circuitry and how operational control is designed. Using the extension equipment sets it is possible to explore even more complex control operations and tasks. The machine equipment set contains all of the motors and equipment required to test direct and indirect control of motors in the three-phase circuit.



Experiment example: "Contactor circuits in the three-phase circuit EST 2"



Industrial contactor circuits

### Training content

- Setting the motor protection relay in accordance with the motor's rating plate
- Protection, safety and disconnection functions
- Project planning, construction and putting complex controls into operation
- Operational testing and trouble-shooting
- Star-delta circuits
- Reversing contactor control with safety interlocking
- Connection of three-phase motors
- Drafting circuit diagrams

# Three-phase Synchronous Machines

## Synchronous motor and generator

Synchronous machines are primarily used as generators in power supply networks. Power levels in this area can reach up to around 2000 MVA. Other additional areas of application are large-scale drives for cement mills and conveyor belt systems with power levels in the megawatt range. Highly dynamic servos with permanently excited rotors complete the spectrum of synchronous machines. In contrast to asynchronous machines, here the rotor operates in sync with the rotating magnetic field.



Experiment example: "Synchronous machines EEM 5.1"

### Training content

#### Motor operation:

- Motor connection
- Starting
- Phase-shift operation
- Load characteristics in motor operation
- V-characteristics
- Stability limits
- Under-excitation and over-excitation

#### Generator operation:

- Generator connection
- Voltage adjustment via the exciter current
- Load characteristics in generator operation

# Three-phase Synchronous Machines

## Manual mains synchronisation

In the case of mains synchronisation the unloaded generator is switched to the mains. Voltage, frequency and phase angle have to coincide with the corresponding variables on the mains. Different measuring instruments are used to measure these variables. The variables are set by means of the generator speed and excitation.



Experiment example: "Synchronous machines EEM 5.2"

### Training content

- Manual mains synchronisation with the aid of synchronising bright method, dark method and three-lamp synchronisation circuits
- Mains synchronisation using two-range frequency
- Two-range voltmeter, synchronoscope and zero-voltage meter
- Influence of the generator speed
- Influence of generator excitation
- Adjusting power flow by means of the drive

## Reluctance machine

Reluctance motors constitute a mixture of asynchronous and synchronous motors. Due to the special design of the rotor with salient pole construction the motor is able to operate like an asynchronous motor. Starting at a certain speed it then locks into synchronous speed with the stator field. Reluctance machines are used, for example, in the textile industry for synchronous despooling of yarn. This involves several motors operating under the control of a frequency converter.



300-W and 1-kW  
power classes available

*"Reluctance machines EEM 5.3"*

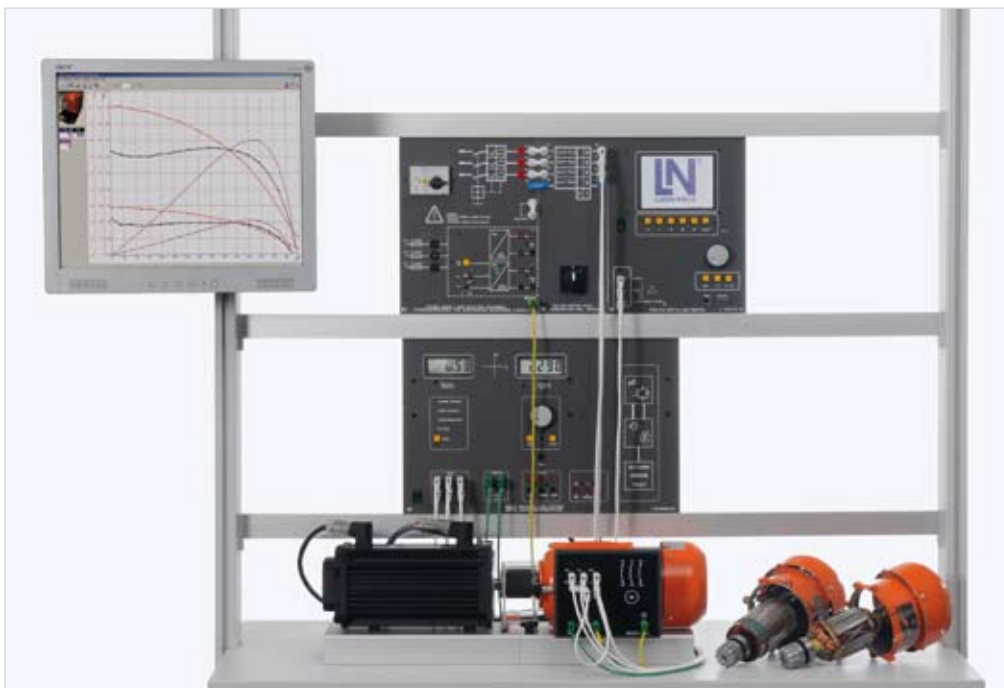
### Training content

- Connecting, wiring and putting into operation
- Reversing the rotation direction
- Recording the speed and torque characteristics

# Three-phase Machines

## Dismountable three-phase machine set

This training system consists of a standard stator for all machine types and a set of interchangeable rotors. Thanks to its dismountable design the set is particularly suitable for teaching the basics since it delves into the various machine construction designs and their differences. Unlike conventional cut-out models these machines are fully operational and can be coupled to the machine testing system.



*Dismountable three-phase machine set EEM 10*



*Open-type stator  
with different rotors*

### Training content

Design and construction differences of three-phase machines as well as connection, putting into operation and recording characteristics:

- Short-circuit rotors
- Synchronous machines
- Slip-ring rotors
- Reluctance machines

# Transformers

## Single-phase and three-phase transformers

Transformers are made to convert currents and voltages. These so-called passive electrical machines are designed to adapt designated equipment to the different voltage levels made available by the power industry. The power levels range beyond 1000 MVA. Small transformers can be found everywhere in industry and in the consumer goods sector. The power classes can range from the smallest version up to the large-scale transformers that supply entire production plants.



Experiment example: "Single- and three-phase transformers ENT 5"

### Training content

- Isolation and autotransformers
- Equivalent circuit diagrams
- Transformation ratio
- No-load and short-circuit experiments
- Vector groups in three-phase transformers
- Design and operation of transformers
- Single-phase transformer
- Three-phase transformer

# Power Electronics and Didactically Designed Drives

## Loss-free control of electrical machines

Power electronics is the technology of switching and converting electrical power to greater power levels. Nowadays we use power semiconductors like diodes, thyristors and IGBTs to perform these operations. The main application area for power electronics is drive technology.

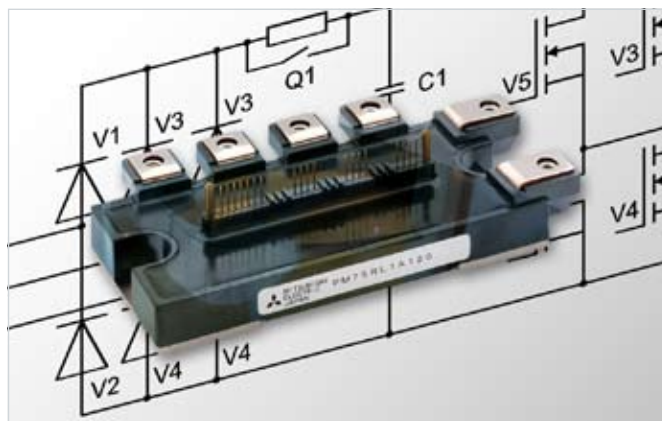
The training systems in this area are designed to explore technical relationships beginning with static converter technology and even include automatically controlled drives. The software is well-conceived and provides the consistent support crucial for both quick and clear experiment set-up and rapid learning success.



### Power Semi-conductors

The rapid developments being made in power semiconductors continue to forge ever newer applications and improvements in electrical drives. Innovations include the following: shrinking power-loss, work with higher frequencies and operation with "intelligent power modules".

These modules contain, in addition to power semiconductors, also the control unit and safety circuitry needed to protect against impermissibly high currents and excess temperatures.



Source: Mitsubishi Electric B.V.

### Automatic control of machines

Many manufacturing processes employ automatic speed-controlled drives or positioning drives. Besides the machine and its associated power electronics it is the automatic control system which exerts a great deal of influence on the drive's response. It is the technician's job to make sure that control operation is suited to the manufacturing process.



### Training systems

Our training systems cover the following topics:

- Line-commutated static converters
- Self-commutated static converters
- Automatically controlled DC drives
- Frequency-converter drives



# Line-commutated Static Converters

## Uncontrolled rectifiers – controlled rectifiers – AC and three-phase AC power controllers

Power electronics is firmly anchored in modern life. Otherwise such things as dimmable halogen lighting, speed-variable drills or electric heating would be impossible. Power semiconductors such as diodes, thyristors and power transistors make this all possible.



**UniTrain**  
SYSTEM

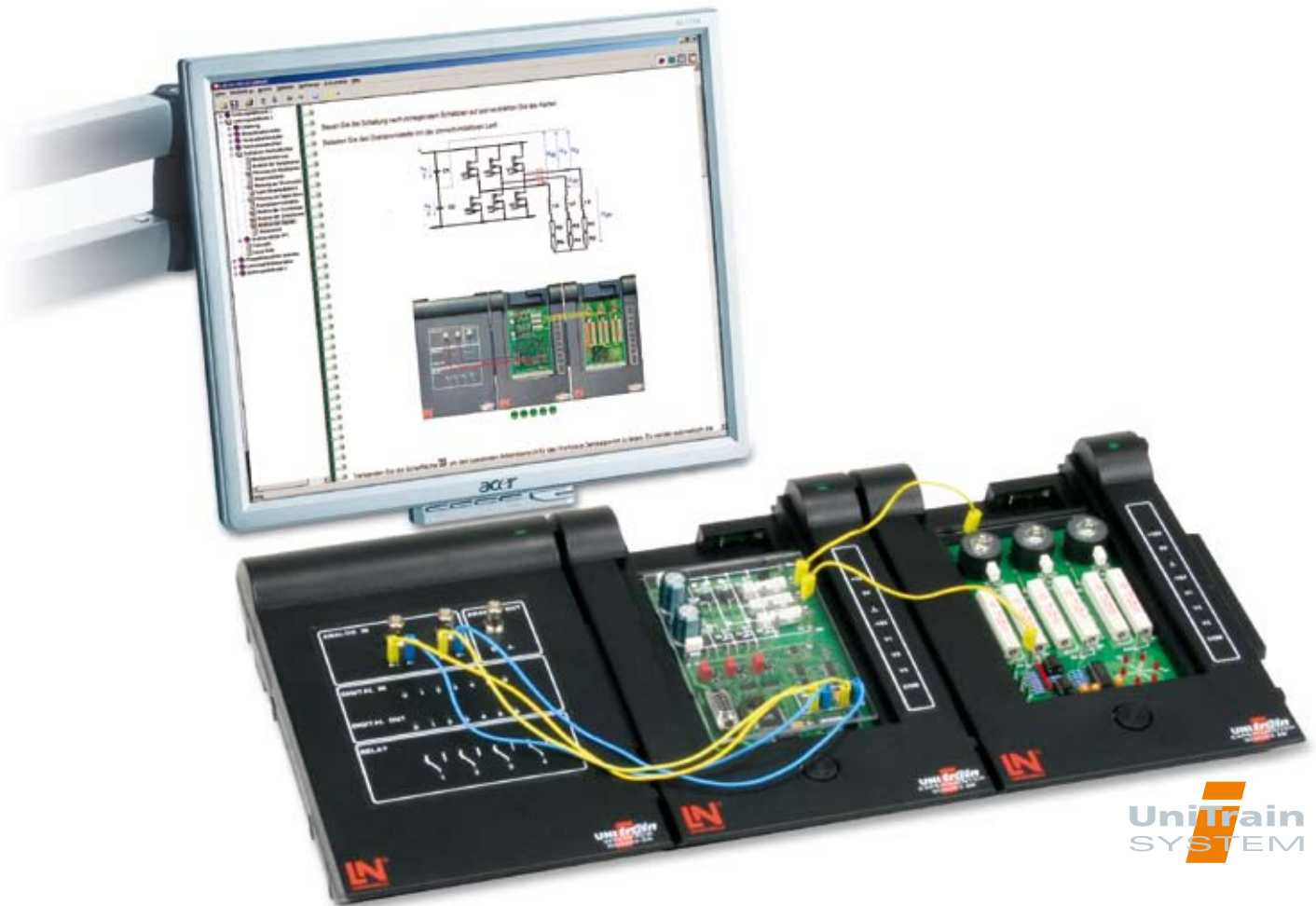
### Training content

- Design and operation of single-phase and three-phase rectifiers
- Operating characteristics of uncontrolled, semi-controlled and fully controlled static converter circuits
- Power semiconductors and their control
- Power electronics measurement variables
- Measurement and analysis of static converter circuit power
- Analysis of current, voltage and transmission using fast Fourier transform analysis (FFT)

# Self-commutated Static Converters

## PWM – 4-quadrant power controller – power inverter

The number of speed-variable drives to be found in modern machines is constantly going up. The reasons for this are the growing expectations and the advent of modern competitively priced power inverters. Today these power inverters work with PWM technology.



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SYSTEM

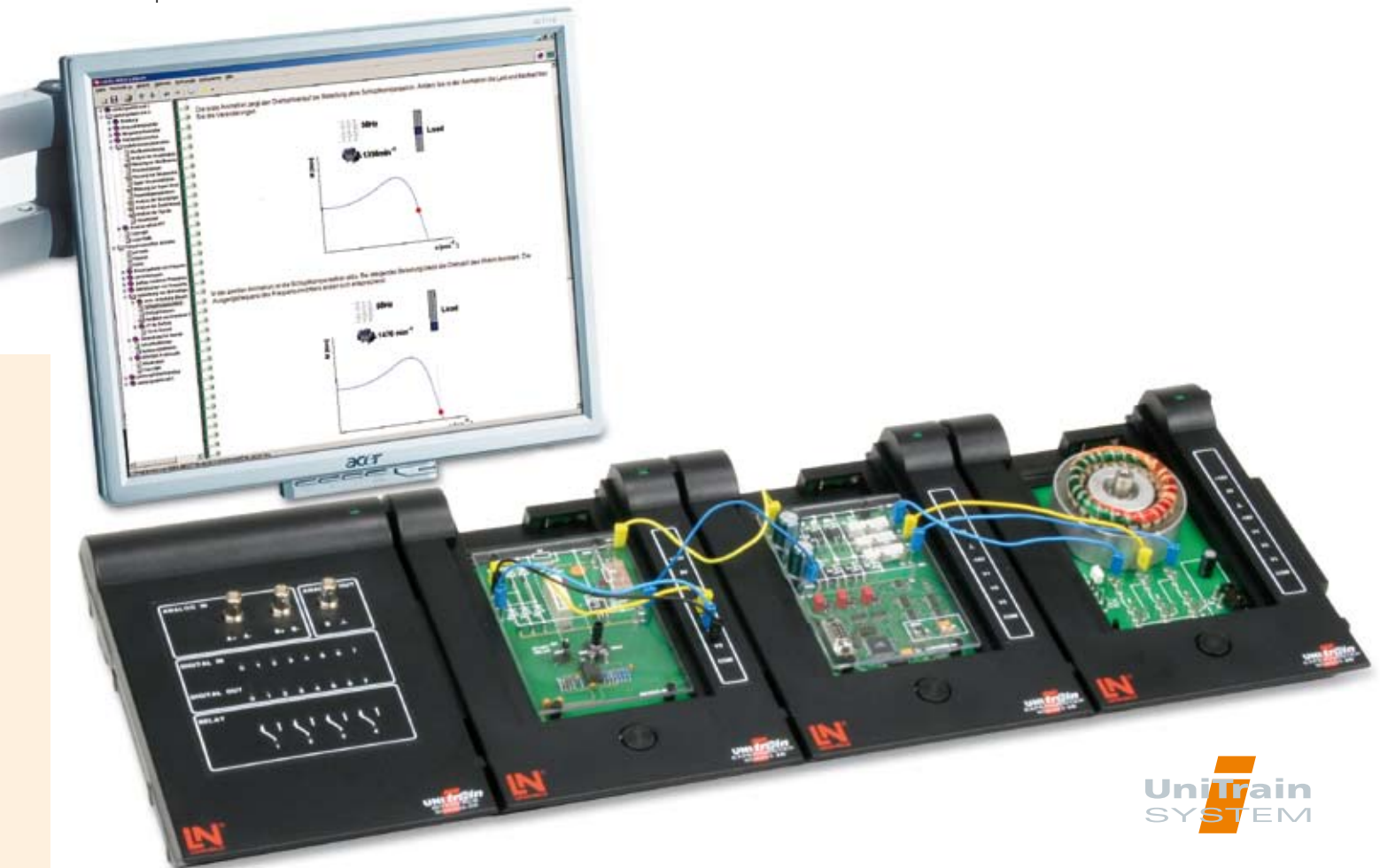
### Training content

- PWM for generating variable DC and AC voltages
- Recording control and operating characteristics
- Design and operation of three-phase AC inverters
- Block commutation, sinusoidal, super and sine and space vector modulation for the generation of voltage- and frequency-variable voltages
- Instrumentation-based analysis of various modulation methods based on signal characteristic measurements and fast Fourier transform analysis (FFT)

# Frequency-converter Drives

## Feed-in – DC link – power inverter – speed adjustment

Frequency converters are responsible for making the low-loss, continuous speed adjustment of three-phase asynchronous motors possible. In addition to pure motor control and motor protection functions, modern frequency converters today are also assuming some process automation tasks.



**UniTrain**  
SYSTEM

### Training content

- Design of modern frequency converters
- Generation of DC link voltages
- Recording U/ f-characteristics
- Design and operation of brake choppers
- Optimisation of speed-controlled drives
- Learning about “87-Hz technology”
- Recording and analysing currents, voltages and power levels

# PFC Power Factor Correction

## Active PFC control – harmonic analysis

Today every mains power supply built into a computer is equipped with PFC (PFC – Power Factor Correction). The reason for this popularity is a European-wide norm that stipulates that as of a particular power level loads have to draw their current from the mains in a linear relationship to their voltage characteristic.



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SYSTEM

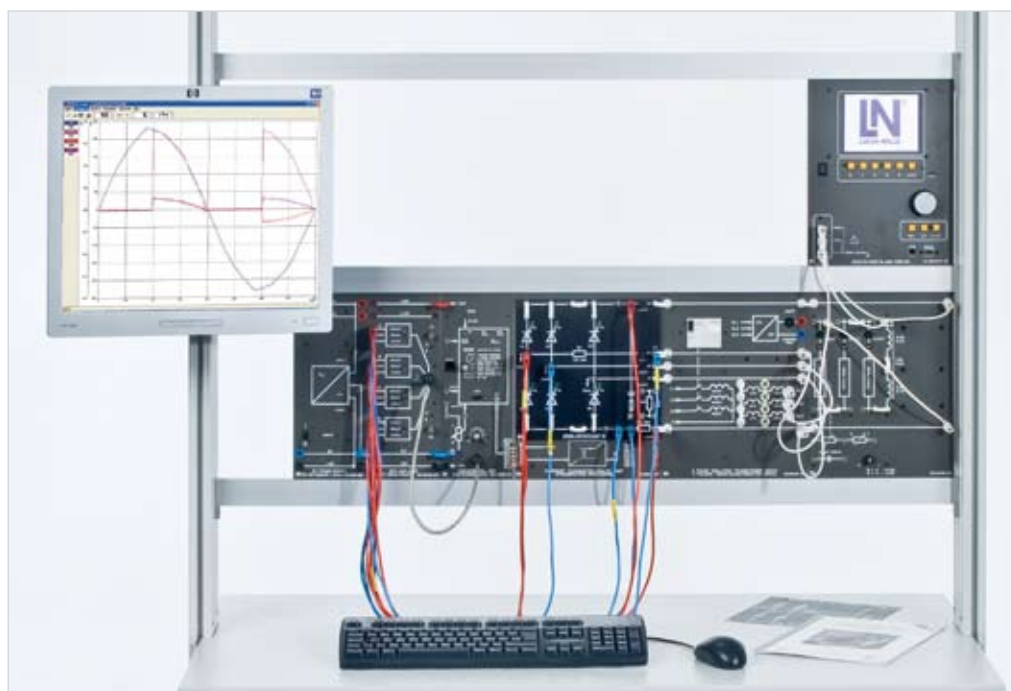
### Training content

- Active and passive power factor correction
- Design and operation of an active power factor correction circuit
- Application areas for power factor correction
- Comparison to conventional bridge rectifier circuits
- Recording and analyzing currents, voltage and power levels (also using FFT)

# Line-commutated Static Converters

## Diodes – thyristors – triacs

Line-commutated static converters permit power to be fed from an AC or three-phase mains into a DC circuit. They can be designed for operation in controlled-mode using thyristors and triacs or non-controlled mode with diodes.



Experiment example: "Line-commutated Static Converters EPE 10"

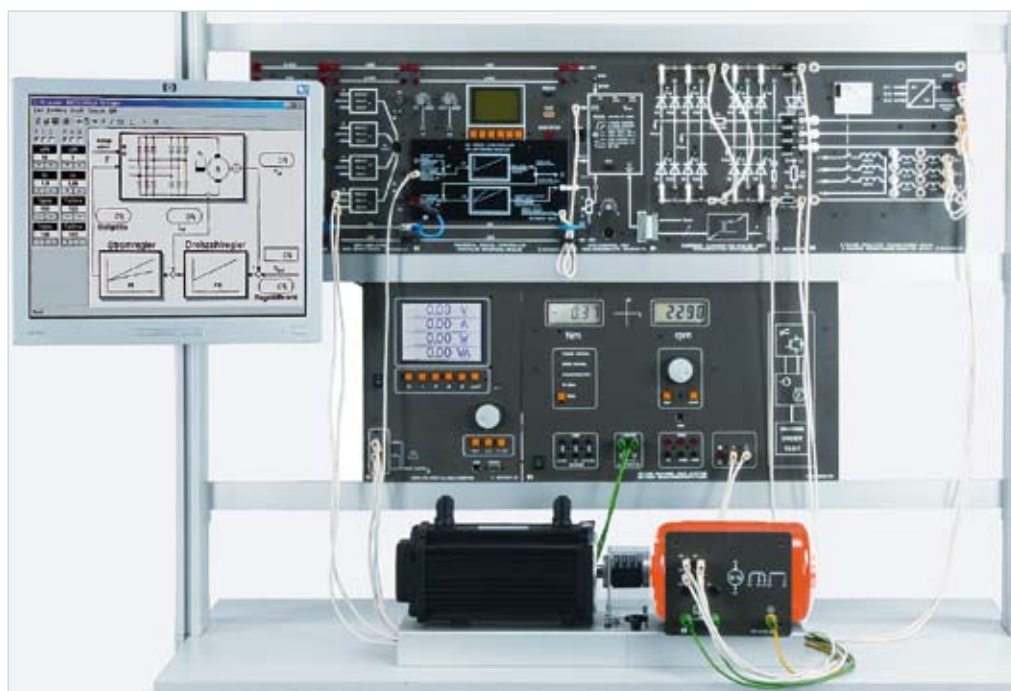
### Training content

- Fundamentals of diodes, thyristors, triacs
- Control principles: phase-angle control, full-wave control, multi-cycle control, pulse-modulation pattern control, rectifier operation, inverter operation
- Static converter circuits: M1, M2, M3, B2, B6, M1C, M2C, M3C, B2C, B6C, B2HA, B2HK, B2HZ, B6C, B6HA, B6HK, W1C, W3C
- Resistive, capacitive and inductive loads
- Control characteristics and operating diagrams
- Frequency and harmonics analysis

# Closed-loop Speed Control of a DC Motor Using Converter Circuitry

## Motors – power electronics – automatic control

Automatically controlled DC drives excel due to their excellent speed and torque controllability and highly dynamic response. When it comes to power semiconductors for large-scale high-powered drives engineers turn to line-commutated converters with thyristors. These components stand out on account of their overload capacity and tendency to low power loss.



Experiment example: "Automatic speed control of a DC motor using static converter circuitry EPE 11"

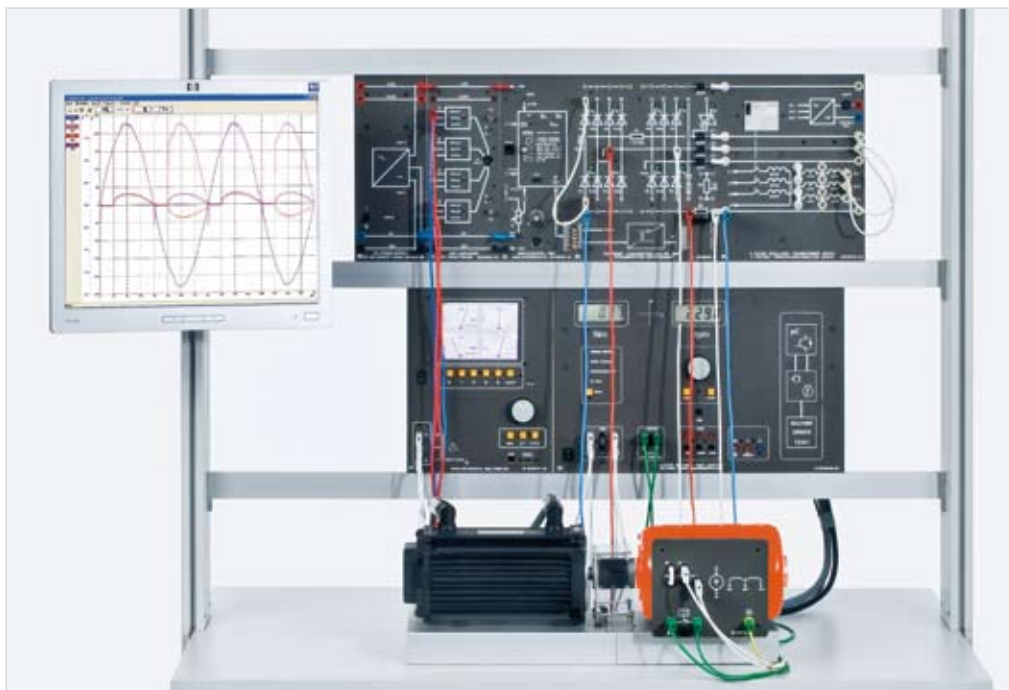
### Training content

- Automatic speed control in 1st and 4th quadrant operation with and without secondary current control
- Energy recovery
- Automatic speed control, current control, cascade control, adaptive control
- Computer-assisted controlled system and controller analysis, parameter optimization
- P-, PI- and PID-action speed control
- Control loop optimization

# Open-loop Speed Control of a Universal Motor

## Simple speed adjustment

Nowadays many portable commercial and household devices are equipped with speed-variable drives. Examples include electronic drills or vacuum cleaners with variable suction power. The use of a universal motor with phase-angle control offers an economical solution to automatic speed adjustment or speed control.



Experiment example: "Open-loop speed control of universal motor EPE 16"

### Training content

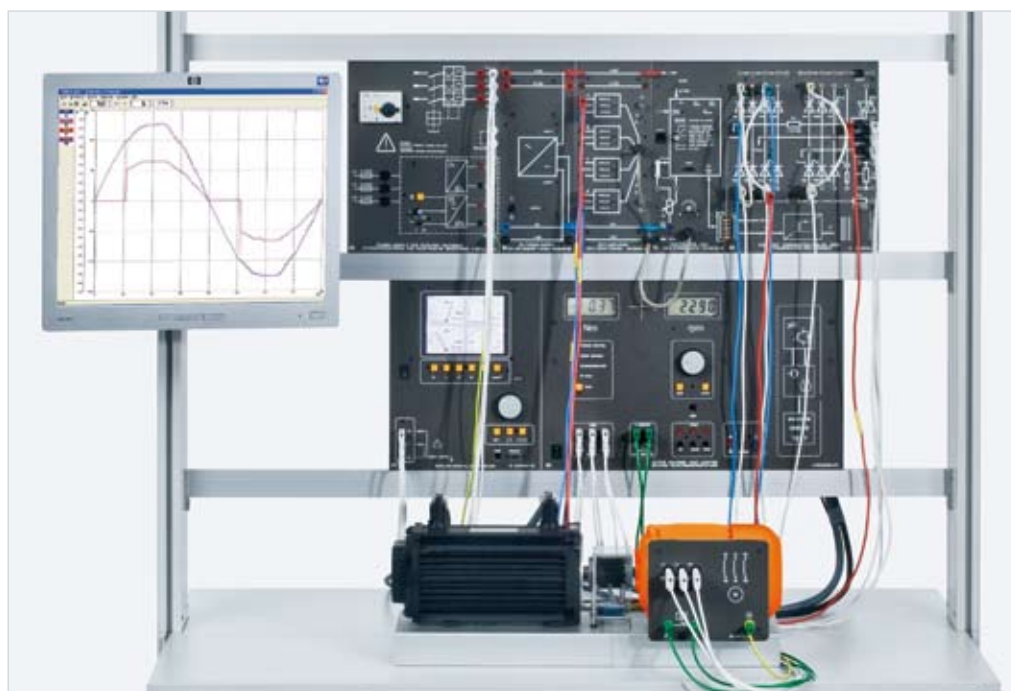
- Open-loop speed control with single-phase inverter circuitry
- Single pulse ignition, multi-pulse ignition, phase control range
- Voltage, current, power characteristics
- Analysis of the fundamental and harmonic spectrum

# Open-loop Speed Control of a Three-phase Motor

## Slip control – smooth starting

Three-phase asynchronous motors with squirrel-cages are the machines most commonly put to use in industry. Frequency converters allow for the open-loop control of machines. Slip control is an alternative made possible by phase-angle control.

This kind of control is frequently implemented in so-called smooth starting machinery. During start up, phase-angle control is used to reduce the effective voltage so that the motor can be switched into the mains without being subject to high switch-on currents. As a rule smooth starting machines replace the star-delta circuit starting.



Experiment example: "Open-loop speed control of a three-phase motor EPE 17"

### Training content

- Open-loop speed control with three-phase and bi-directional connection
- Single-spark ignition, multi-pulse ignition, phase control range
- Electronic smooth starting and slip control
- Voltage, current, power characteristics
- Analysis of the fundamental and harmonic spectrum

# Self-commutated Static Converters

## IGBT – PWM controller – inverter controller

By self-commutated static converters we mean converters that convert DC and AC currents using components that switch on and off. These valves are able to commute on their own without line commutation. Self-commutated converters operate like inverters with load-independent voltages and currents.



Experiment example: "Self-commutated converter EPE 20"

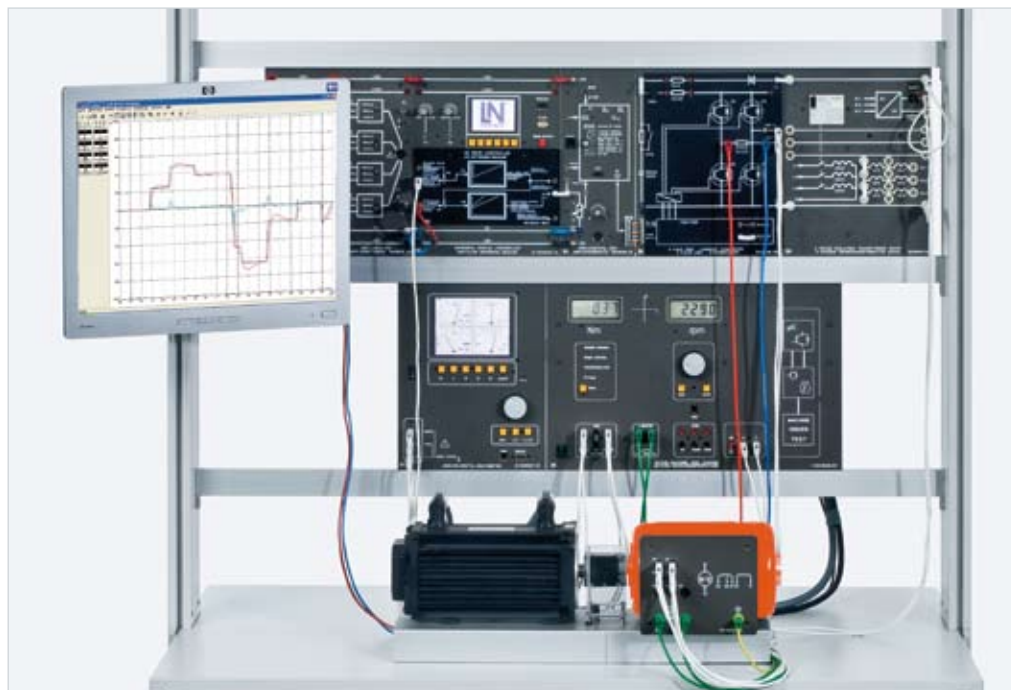
### Training content

- Fundamentals of IGBT
- Control principles: pulse width modulation, DC chopper controllers in 1, 2 and 4-quadrant operation
- Modulation of low frequency AC voltage with pulse width modulation
- Circuits: step-down controller, H-bridge, inverter
- Resistive, capacitive and inductive loads
- Protective circuits, intermediate link circuit, free-wheeling circuit
- Control characteristics and operating graphs
- Frequency and harmonic analysis

# Closed-loop Speed Control of a DC Motor Using PWM

## Motors – power electronics – automatic control

Automatically controlled DC drives stand out for their excellent speed and torque controllability and in terms of their dynamic response. In low and medium drive power classes the components of choice among semiconductors are the self-commutated converters with transistors or IGBTs. High operating frequencies allow for highly-dynamic control response and low torque ripple.



Experiment example: "Closed-loop control of a DC motor using PWM EPE 21"

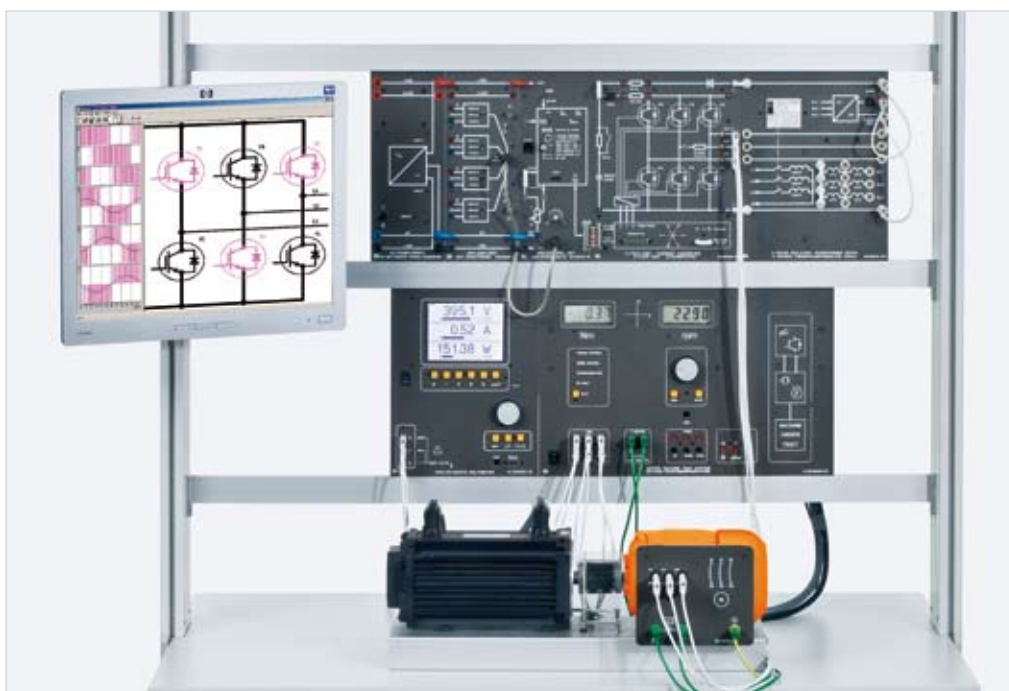
### Training content

- Closed-loop control in single and 4-quadrant operation with and without secondary cascade current control
- Closed-loop speed control, current control, cascade control, adaptive control
- Computer-assisted controlled systems and controller analysis, parameter setting
- P-action, PI-action, PID-action speed control
- Controller optimisation

# Frequency Converter Drives

## Mains rectifier – DC link – inverter – motors

Today, frequency converter technology permits three-phase asynchronous motors with short-circuit rotors to be controlled with practically no power loss whatsoever. Robust and price-efficient motor construction is combined with fully developed frequency converters to open up the widest range of potential applications.



Experiment example: "Frequency converter drives EPE 26"

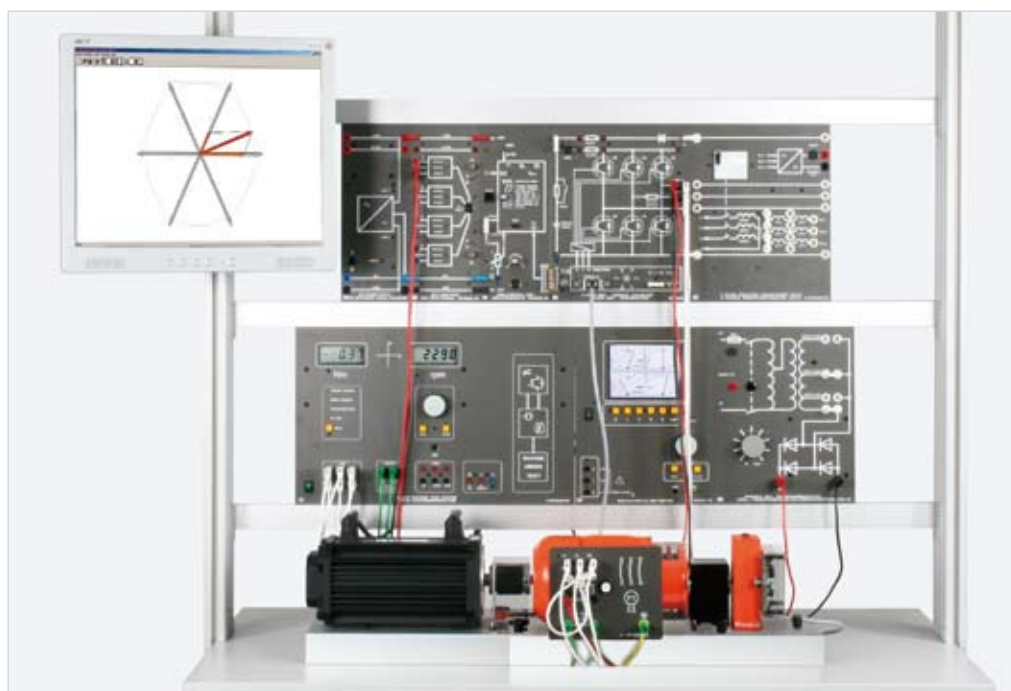
### Training content

- Investigation of converter control of voltage and frequency
- Investigation of converter control using space vector modulation
- Analysis of voltage and frequency relationships
- Stator resistance compensation
- Investigation of converter drives
- Computer-assisted parameterization and animation

# Electronically Commutated Motors

## Load-commutation

One special type of synchronous machines is the electrically commutated machine. These machines work with variable frequency fed from a voltage converter. Thanks to the rotor position's feedback signal this machine achieves the speed-torque response of a separately excited DC shunt-wound machine. One particularly huge benefit here is that the power electronics makes commutation virtually wear and tear-free.



Experiment example: "Electronically commutated motor EPE 27"

### Training content

- Operating principle of a servo motor using electronic commutation
- Analysis of field-oriented space-vector modulation
- Investigating coordinate and sensor systems
- Computer-assisted parameterization and animation

# Industrial Drives

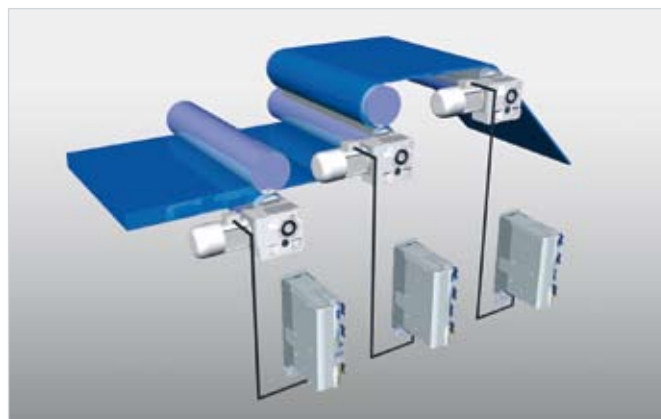
## Parameterization of industrial components

Today, the idea of a modern industrial world without controllable electrical drives is totally unthinkable. Their area of application ranges from high power performance to traction drives, machine tools and production machines up to and including applications in the automotive sector. As opposed to didactically designed drives these training systems are equipped with industrial equipment. The training here focuses on how to handle and set the parameters of real industrial drive equipment.



### Industrial components

The use of industrial components made by well-known manufacturers such as Lenze AG or Siemens puts us in a position to convey practical industrial know-how directly to the student. The designations of all of the terminals and connections correspond exactly to equipment used in industry. Standard industrial operating instructions and software are used in the projects and exercises.



### Multi-disciplinary

Field-bus interfaces in connection with frequency converters, servo drives and motor management relays provide the basis for interdisciplinary applications together with automation technology. The drives can be controlled via PLC and operated using HMIs. This permits the visualisation of typical process control variables, disturbance variables and operating modules.



### Training systems

Our training systems cover the following topics:

- Smooth starter
- Frequency converter drives
- Servo drives
- Motor management relays



# Smooth Starting of Three-phase Machines

## Cutting high switch-on currents

Smooth starters use phase angle control to reduce the motor's voltage during switch-on. The starting current drops proportionally to the terminal voltage. The power section of a smooth starter normally consists of two thyristors switched anti-parallel per phase. In order to be able to keep the power losses and the associated heat build up as low as possible, the power semiconductors are shunted by a power circuit-breaker subsequent to the starting phase.



Experiment example: "Smooth starting of three-phase machines EDT 17"

### Training content

- Putting the circuit into operation
- Setting the parameters for run-up, run down and starting voltage
- Examining the current and voltage levels during starting
- Starting under different load scenarios
- Comparing star and delta start-up

# Drives with Frequency Converters

## The variable speed drive

Modern frequency converters transform any given three-phase standard motor into a drive with variable speed. The robust nature and popularity of three-phase standard motors have made a significant contribution to the huge success that electronic drive technology with frequency converters enjoys. The higher demands being made of drives due to developments in process automation means that more and more motors are being controlled by frequency converters. Thanks to customised open-loop speed control, today pumps and air-conditioning units are able to save a substantial amount of energy.



Experiment example: "Drives with frequency converters EDT 25"

### Training content

- Computer-assisted set-up and operation
- Parameterization of setpoint variables, rotation direction, starting operation, operating frequency, limiting values, nominal voltage, nominal current, rated frequency, power factor etc.
- Investigating the operating response under working machine loads
- Recording the speed and torque characteristics across all four quadrants
- Drive optimization
- Operation with a brake chopper
- Operation with vector control

# Frequency Converter Project Work

## Design – industrial wiring – putting into operation

Using the training system titled “Frequency Converter Project Work”, trainees learn hands-on how to set up and wire the industrial components found in a control cabinet. By using frequency converters with compact controls, the ideal combination between drive and process control technology is found. The result is a system that allows different industrial projects to be designed, set-up, parameterized and tested. By integrating servo and machine test stands it is possible to subject the final projects to testing under realistic conditions.



Experiment example: “Frequency converter project work EPL 25”



Operating elements

### Training content

- Drafting, implementing and analysing circuit diagrams
- EMC approved set-up and wiring of the control cabinet equipped with industrial components
- Putting the system into operation
- Approval and acceptance according to DIN EN
- Protective conductor measurement
- Insulation measurement
- Parameterization of the frequency converter
- Programming the LOGO!® compact control unit

# Open-loop Control of Electrical Drive Systems

## Link between drive and automation engineering

This training system features project planning and programming of the PLC unit and the operator panel. It also covers the putting into frequency converter into operation and setting its parameters using PROFIBUS-DP. To submit the frequency-converter controlled drive machine to load, this training system uses a servo brake. Overall an array of controllable working machines like ventilators, winding drives, calanders, compressors or flywheels can be simulated in this system.



Experiment example: "Open-loop control of electrical drive systems CLP 20"

### Training content

- Parameterization, programming and the putting into operation of a programmable logic controller
- Project planning and putting into operation of an operator panel
- Parameterization and putting into operation of a frequency converter
- Project planning and putting into operation of a field-bus system
- Parameter optimization on different adjustable working machines

# Positioning with the Synchronous Servo System

## Always the right position

When people talk about servo drives today, they generally mean highly dynamic three-phase drives. Servo drives primarily perform positioning tasks in tooling machines, manipulators or robots. But more and more these devices are finding their way into printing machines, conveyor belts and cutting machinery where precise positioning or angular alignment are required.

Here servo converters, motors with sensor technology and mechanical transfer elements form an extremely integrated system whose components have to be seen as a single entity.



Experiment example: "Positioning with synchronous servo system EDT 32"

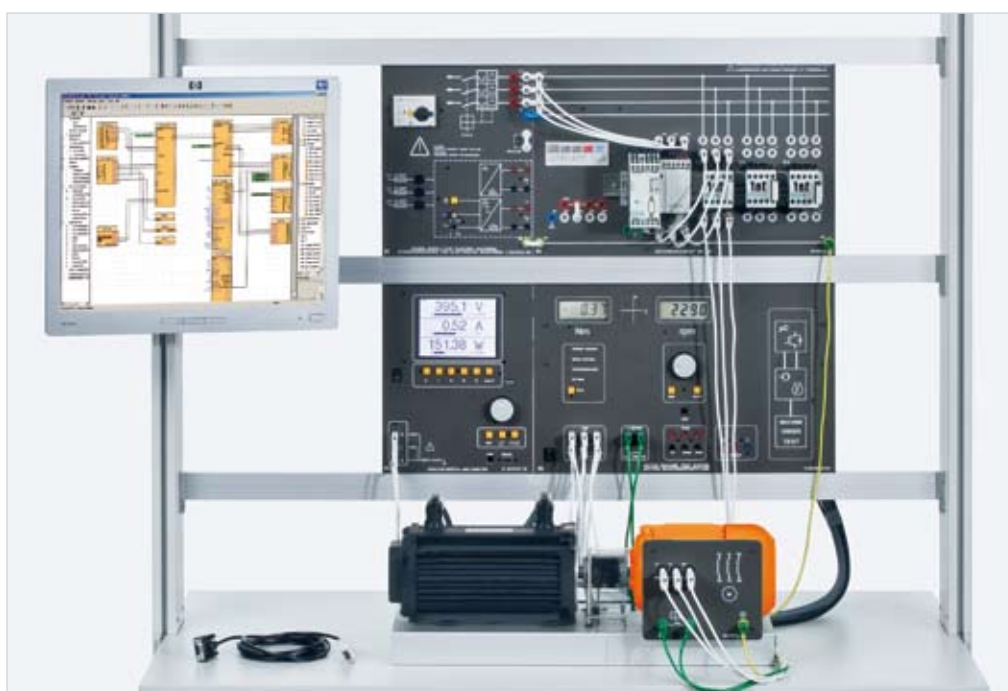
### Training content

- Computer-assisted set-up, putting into operation and parametrization of a servo drive with linear axis
- Positioning and sequential control
- Parameterization of position and speed controller using a simple industrial parameter setting software
- Reference travel function
- Investigating the effects of different controller settings on different loads

# Motor Protection/Motor Management

## Effective motor protection – preventive maintenance

Motor management systems are put into action in modern automation systems and make it possible to provide drives and processing systems with the optimum protection, control and monitoring system. These systems permit the detection of, for example, the motor temperature, voltage or current. The transparency of the motor and its functions is enhanced thanks to the field-bus system (e.g. PROFIBUS) that connects it to the primary process automation system. Consequently, the motor's operating capacity and energy consumption can be determined without having to perform measurements on site.



Experiment example: "Motor management relays EDT 52"

### Training content

- Computer-assisted set-up and putting into operation
- Programming such operations as direct start-up, star and delta starting, starting pole-switchable motors, motor protection
- Parameterization of the overload variables and switch-off response under different loads
- Measuring dynamic processes during start-up
- Preventive maintenance

# Decisive Product Benefits

... provide customers with long-term satisfaction



## Mr Georg Greshake, Teacher at Heinz-Nixdorf-Berufskolleg (Vocational College) in Essen:

"As always, the Lucas-Nülle training systems for drive technology just thrill me", says Georg Greshacke, a teacher at Heinz-Nixdorf-Berufskolleg in Essen, "I have been using the servo machine test stand for many years now in mechatronics studies and I'm always completely satisfied with how the equipment performs during instruction.

Only just recently we upgraded and refurbished our vocational college laboratories and workshops with training equipment from Lucas-Nülle. We were impressed by the systems' high quality, didactically sound design and practice-tested conceptualisation.

By implementing the entire program, I can systematically plan out the entire training program, including the deliberate and careful introduction of industrial applications. The modular design of the system is one proven and integral feature.

The UniTrain-I system is used by the students to explore the important fundamentals. After this, they move on to the training panel system. The servo and machine testing stand provides for impressive and realistic simulation of the industrial standard for instructional purposes.

It provides a true-to-life simulation of a wide range of different load machines. Even motor run-up experiments can be performed independently by the students. This enables them to reach a very high level of learning in a very short time and makes experimenting on one's own easier.

Ultimately our students are able to take the experience they collect during instruction and transfer it wholesale into hands-on work performed in true-to-life conditions in the training centre.

# The Whole is Greater than the Sum of its Parts

## Individual consultation with Lucas-Nülle

**Do you require comprehensive advice or a firm offer?**

**You can reach us using any of the following means:**

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Fax: +49 2273 567-69

E-Mail: [vertrieb@lucas-nuelle.de](mailto:vertrieb@lucas-nuelle.de)

**Lucas-Nülle is a byword for custom occupational training systems in the following areas:**



Electrical Installation Technology



Electropneumatics and Hydraulics



Electrical Power Engineering



Instrumentation Technology



Power Electronics,  
Electrical Machines, Drive Technology



Microcomputers



Fundamentals of Electrical Engineering and  
Electronics



Automation Technology



Communications Technology



Automotive Technology



Automatic Control Engineering  
Regelungstechnik



Laboratory Systems

**Ask for detailed information using any of the given methods of contact.**

**Our staff will be happy to advise you.**

**Additional information on our products can also be obtained at:**

[www.lucas-nuelle.de](http://www.lucas-nuelle.de)

[www.unitrain-i.de](http://www.unitrain-i.de)

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