Electrical Machines

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.

Lucas-Nuelle

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.

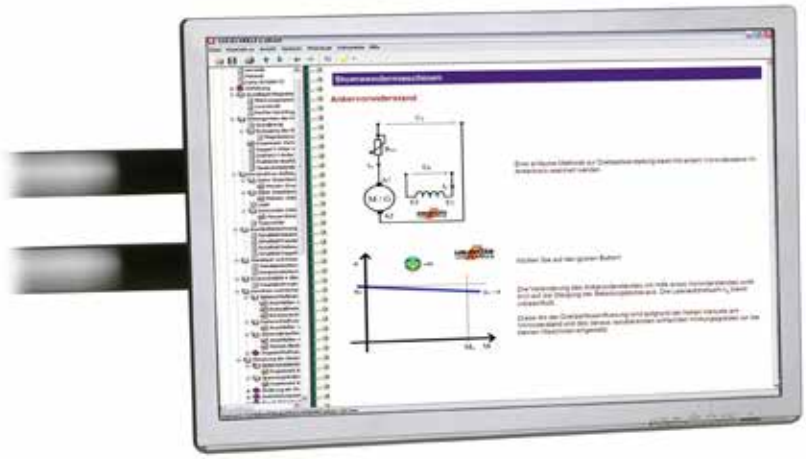
Training systems
The training systems are designed to convey the basic knowledge of electrical machines, demonstrating how they work and displaying their characteristics. The fundamentals of electrical machines are graphically presented using many examples, explanations, exercises and practical assignments.

- UniTrain "Electrical Machines"
- Training panel system "Electrical Machines"

DC Machines

Shunt-Wound Machines – Series-Wound Machines – Compound-Wound Machines – Universal Machines

The DC machines continue 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

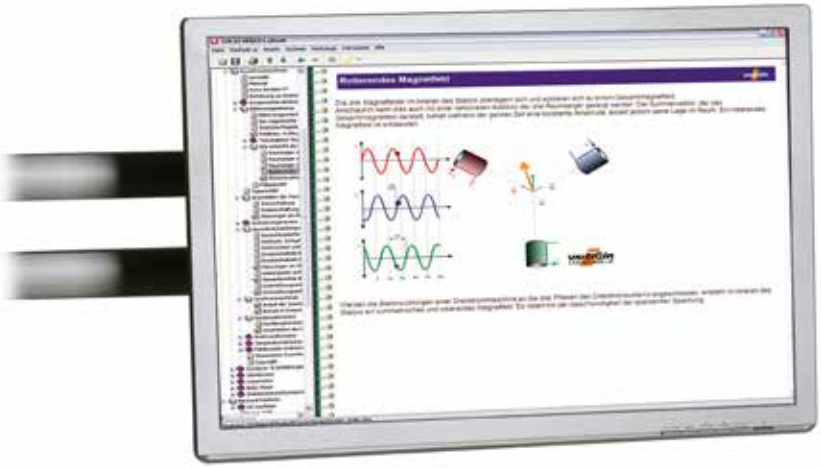
Training content

- Shunt-wound, series-wound, compound-wound, universal machines
- 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
- Trouble-shooting

Synchronous and Slip-Ring Machines

Slip-Ring Rotor Machines – Synchronous Machines – Reluctance Machines

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

UNITRAIN SYSTEM

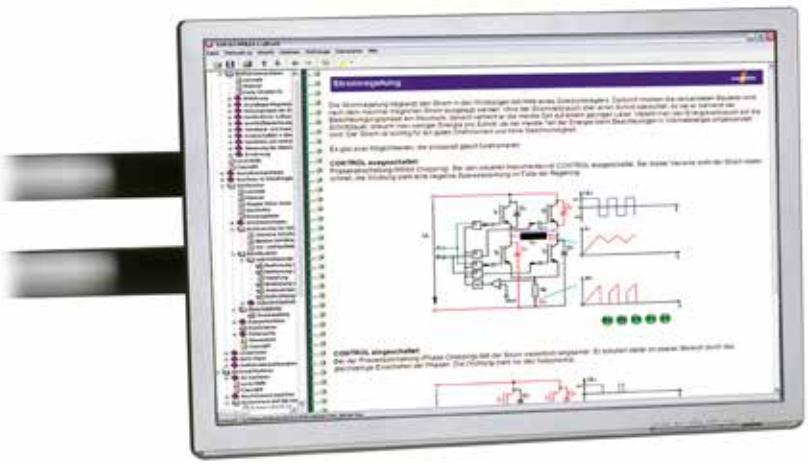
Training content

- 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

Stepping Motor

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

BLDC / Servo Motor

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

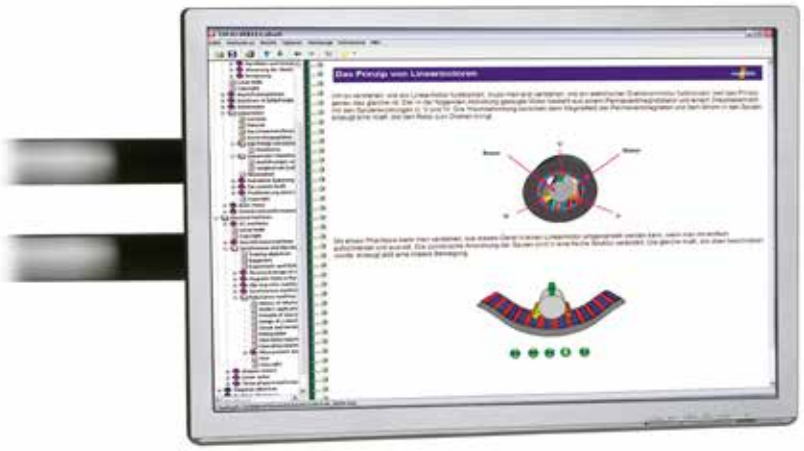
Training content

- 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 Motor

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

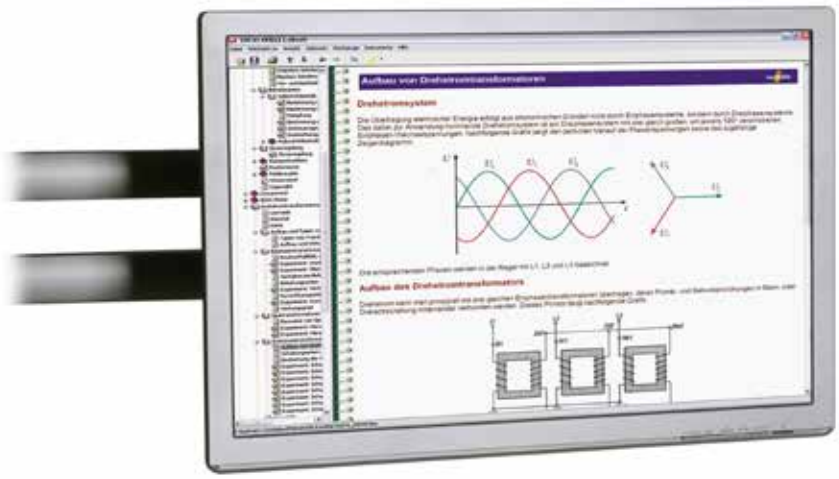
Training content

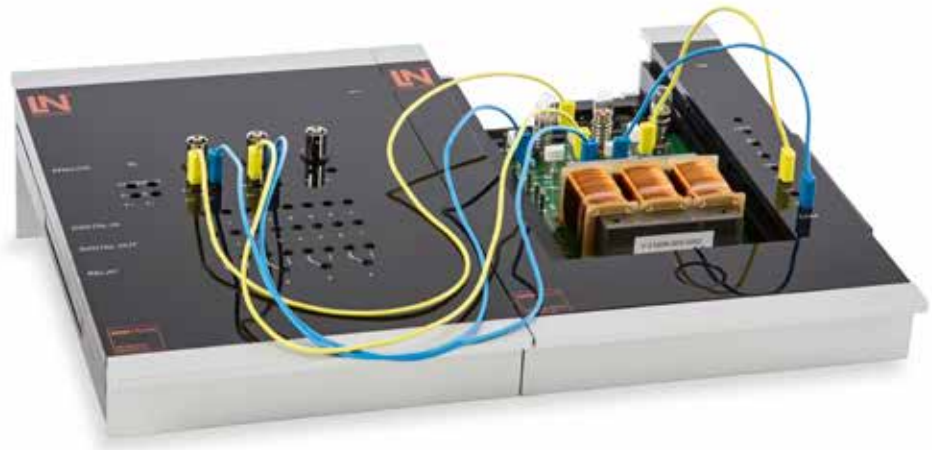
- Design, operation and operating responses of linear motors
- Meaning of the terms “Lorentz force” and “induced voltage”
- Applications for linear motors
- Different designs of linear motors
- Determining the motor constants
- Positioning operations with the linear motor
- Methods of detecting position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

Single & Three-Phase Transformers

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.





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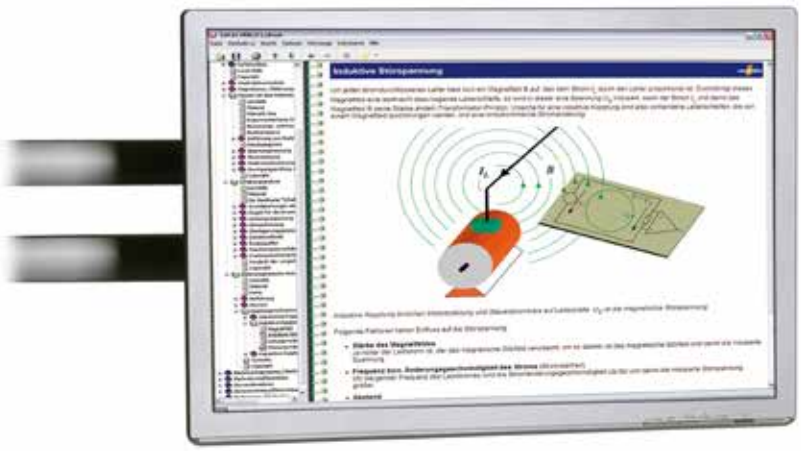
Training content

- Become familiar with the transformer principle and the equivalent circuit diagram
- 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 (EMC)

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

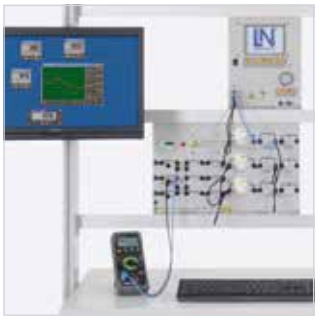
Training content

- 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

Winding Transformer Coils

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.



Wound transformers under test

Experiment example: "Winding transformer coils EMW 10"

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

Winding Electrical Machine Coils

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 test stand.

Wound motor under test

Experiment example: "Winding electrical machine coils EMW 20"

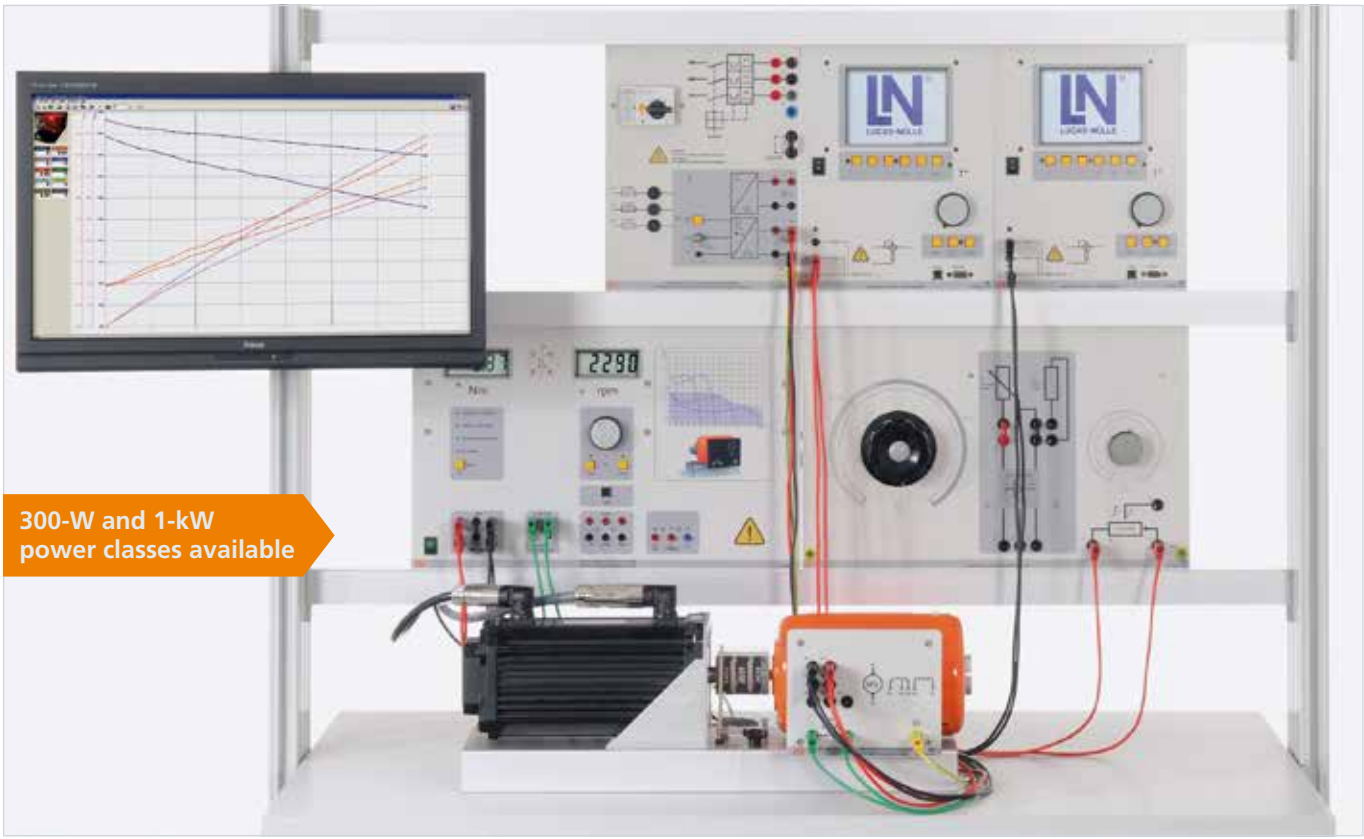
Training content

- Electrical and mechanical design motors
- Determining the winding data
- Producing windings
- Inserting and wiring coil windings
- Testing motor operation according to standards
- 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.



300-W and 1-kW power classes available

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: "AC machines 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

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 operate at a fixed, virtually synchronous speed. The power range reaches up to approx. 2 kW.

Experiment example: "Single-phase motor with bifilar starter winding EEM 3.3"

Training content

- Connecting, wiring and putting into operation
- Reversal of rotation direction
- Recording the speed and torque response
- 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

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

Asynchronous Machines

Three-Phase Motors with Spuirrel-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 also inexpensive to produce. The 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 enabling evermore application areas to be 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, Pole-Switchable Motor According to Dahlander

Due to the special winding, the three-phase motor with a 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 speed and torque characteristics
- Operation with different load machines such as ventilators, hoisting equipment

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 speed and torque characteristics
- Operation with various load machines such as ventilators, hoisting equipment

Fault Simulation on Electrical Machines

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.

Experiment example: "Fault simulation on electrical machines EEM 4.5"

Open fault simulator

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

Protection for Electrical Machines

Squirrel-cage motors were designed to operate with constant loads. Load changes as well as high start-up currents lead to excessive 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 for 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 loads

Manual Switching in Three-Phase Circuits

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, appropriate switching equipment is provided for each application.

Experiment example: "Manual switching in three-phase circuits EST 1"

Training content

- Manual switching in the three-phase circuit
- 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

Contactor Circuits in Three-Phase Circuits

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 three-phase 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
- Compact programmable control
- Star-delta circuits
- Reversing contactor control with safety interlocking
- Connection of three-phase motors
- Drafting circuit diagrams

Synchronous / Reluctance Machines

Synchronous Motors and Generators

Synchronous machines are primarily used as generators in power supply networks. Power levels in this area can reach up to around 2,000 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:

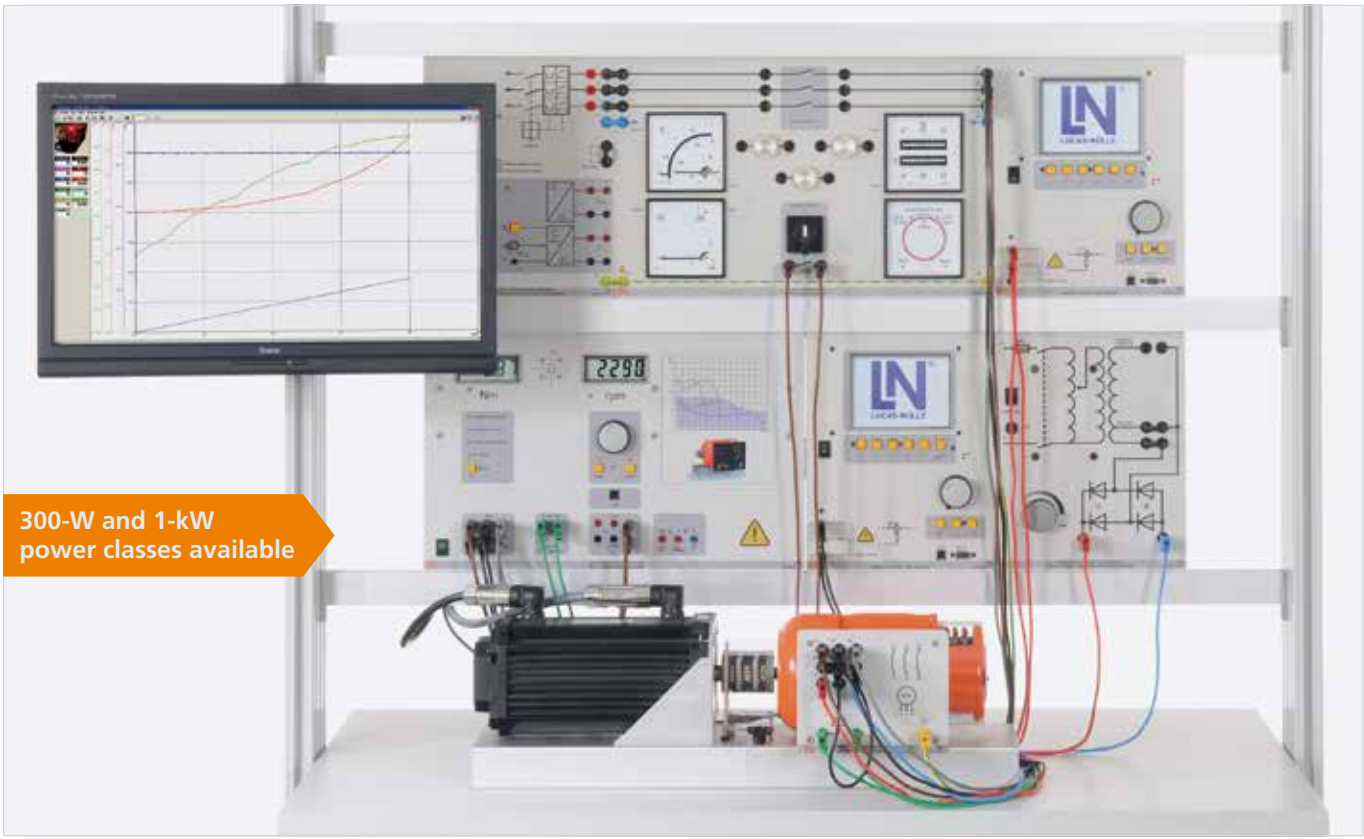
- Motor connection
- Starting
- Phase-shift operation
- Load characteristics in motor operation
- V characteristics
- Stability limits
- Under-excitation and over-excitation

Generator operation:

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

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.



300-W and 1-kW power classes available

Experiment example: "Mains synchronisation 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

Three-Phase Reluctance Machine

Reluctance motors constitute a cross between 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.

Experiment example: "Three-phase reluctance machine EEM 5.3"

Training content

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

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 test system.

Equipment example: "Dismountable three-phase machine set EEM 10"

Training content

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

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

Transformer Trainer

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 1,000 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: "Transformer trainer ENT 5"

Training content

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