LUCAS-NÜLLE

SMART MICRO GRID

eCO2Train

TRAINING SYSTEMS FOR ELECTRICAL POWER ENGINEERING

The Complete Power Supply Network with Renewable Energies

6th Edition

Contents

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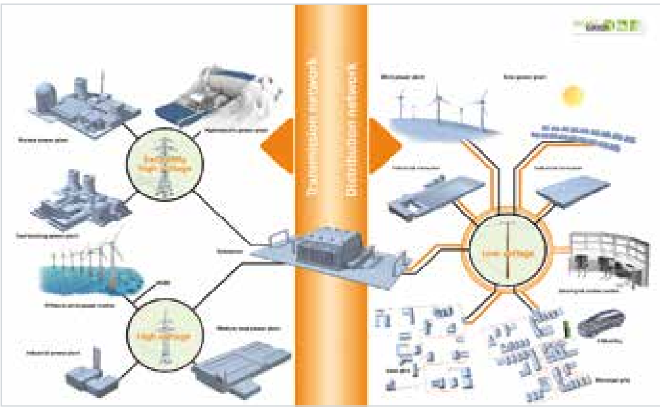
Qualifications Through Quality

Training Systems for Electrical Power Engineering

Advances in technology ...

The transition in the energy industry away from coal, oil and nuclear power towards renewable energy sources is gaining momentum. Today, technology is so advanced that solar energy, wind power, hydrogen power and biomass can be exploited as environmentally friendly energy sources.
In order for this trend to continue, well-trained technicians and specialists are needed all over the world.
In the wake of so-called intelligent (smart) power grids, people all over the world are talking about power generation, transmission and distribution as well as the protection of power engineering facilities and the economic exploitation of energy.



... are having a huge impact on training and education

Now, the Lucas-Nülle training system on power engineering gives instructors the opportunity to demonstrate and convey the technological context of power engineering to students in a graphic and practice-oriented fashion.
Electrical power engineering includes the areas of power generation, transmission, distribution and electrical energy utilisation as well as safety protective measures used in these areas.
The system is so extremely versatile that it can be adapted to fit all of the wide-ranging training requirements applicable to skilled workers, technicians or even engineers.

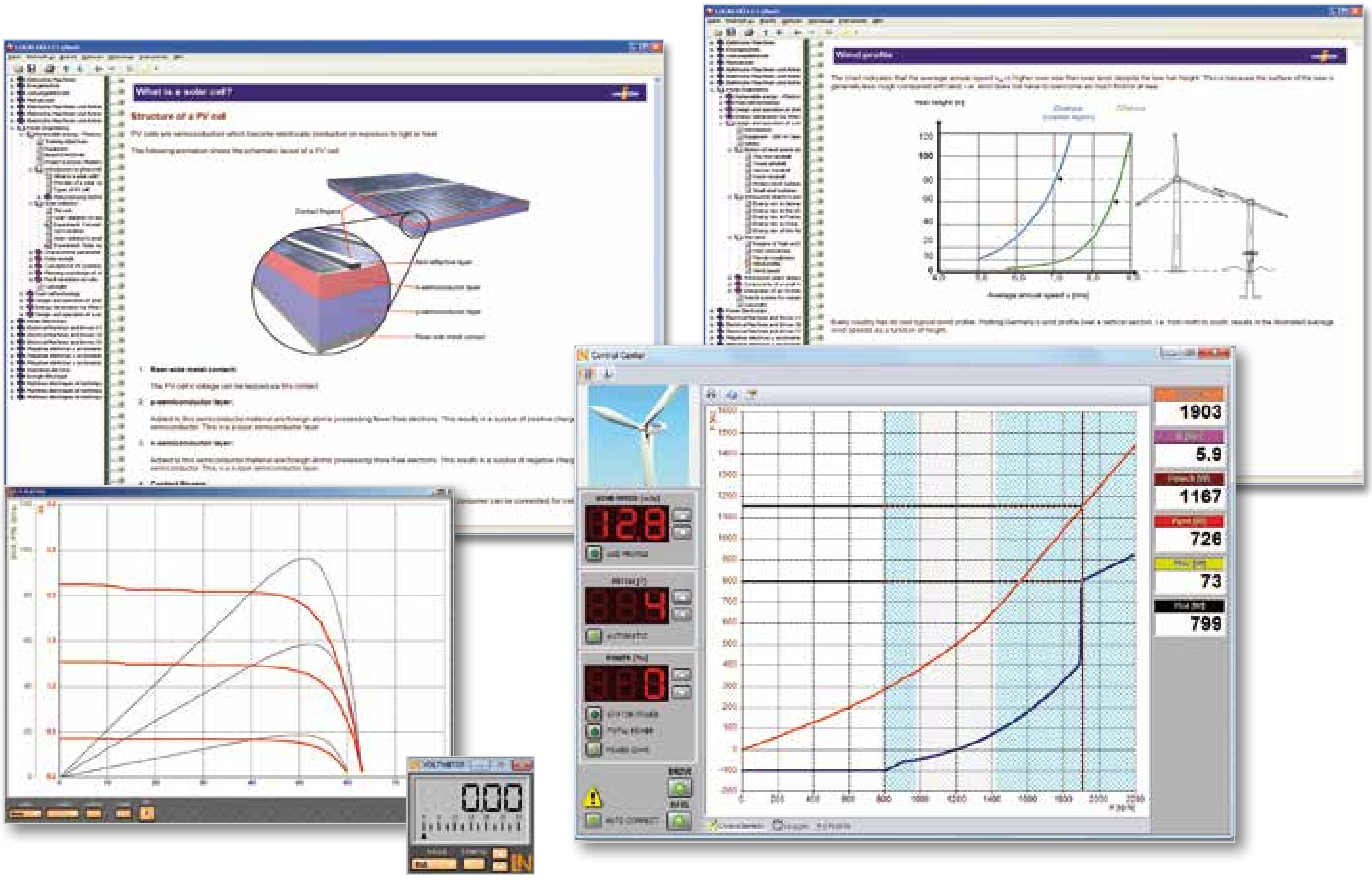
Your benefits

- Comprehensive, well-rounded program – spanning power generation and distribution techniques all the way to energy usage and consumption
- Integration of renewable energies into conventional power engineering
- System monitoring and controlling using SCADA (Supervisory Control and Data Acquisition)
- Modularly designed experiment panel system for the step-by-step, experiment-based exploration of system interdependencies
- Bus structure of all voltage levels permits rapid and transparent experiment setup
- Realistic simulation model of a 380-kV transmission line with 300-km and 150-km sections
- Use of conventional industrial components in cutting-edge digital technology
- High work-safety standards through the exclusive use of safety sockets and safety connecting leads
- Protective technology measures for all areas of power engineering

Animated Presentation of Complex Training Contents

Computer-based Learning Platform - Interactive Lab Assistant (ILA)

Interactive Lab Assistant (ILA) gives you all the support you need for carrying out experiments. It not only provides instructions, it also supplies valuable theoretical information, records measurements and automatically creates the necessary laboratory documentation in the background in the form of a printable document or a PDF file. If you want to change the experiment instructions, you can simply use Labsoft Classroom Manager to modify or add content.



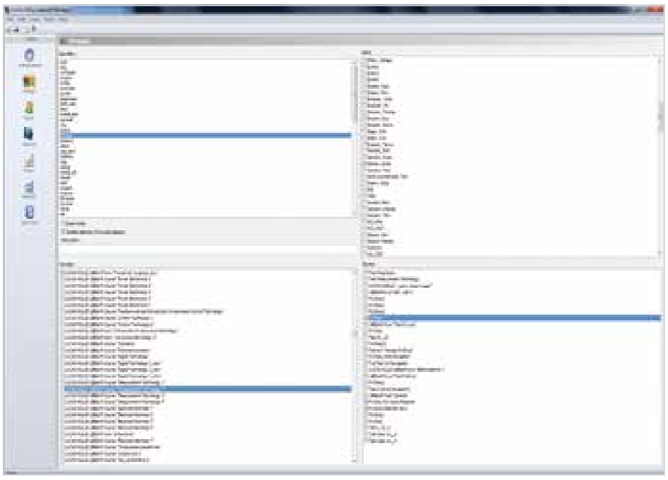
Your benefits

- Theory conveyed using easily understood animations
- Support whilst carrying out experiments
- Interactive display of experiment set-ups
- Access to actual measuring instruments and testers with extensive evaluation capabilities
- Practically oriented project exercises to perfect successful learning
- Integrated operating instructions
- Documentation of experiment results (creation of an experiment report)
- Knowledge tests including feedback function
- Includes SCADA Viewer software with appropriate measuring exercises

Animated Presentation of Complex Training Contents

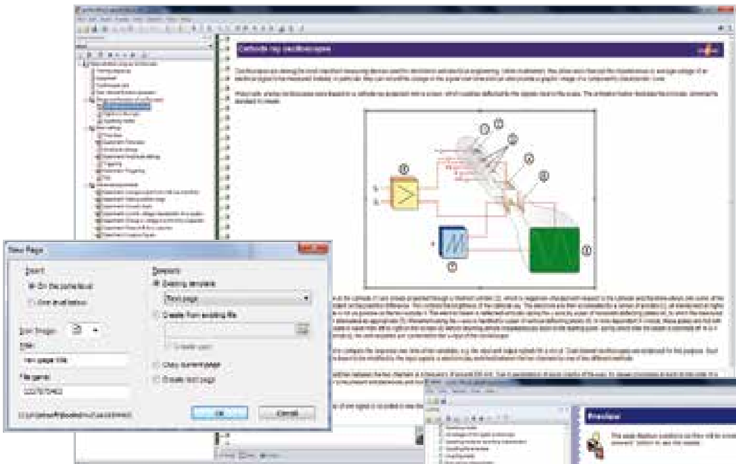
LabSoft Classroom Manager

LabSoft Classroom Manager is an administration software package with extensive functionality. It allows practically oriented training and learning processes to be organised and managed in comfort. Classroom Manager is suitable for all LabSoft-based training programs, such as ILA, UniTrain, InsTrain and CarTrain. It consists of the following sub-programs:

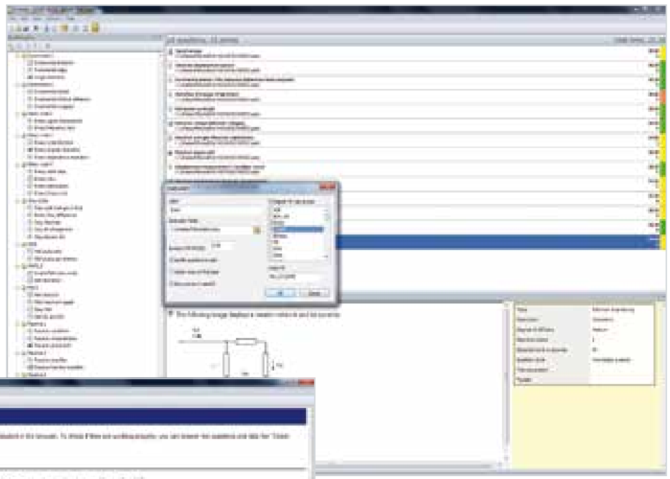


***LabSoft Manager:** Manage your LabSoft courses, students and student work groups with LabSoft Manager. Then students can always be provided with the best training content for their needs.*

***LabSoft Reporter:** Learning progress and test results can be presented for analysis by means of LabSoft Reporter. Targeted monitoring allows for multiple ways of evaluating individual or group results from courses or tests.*

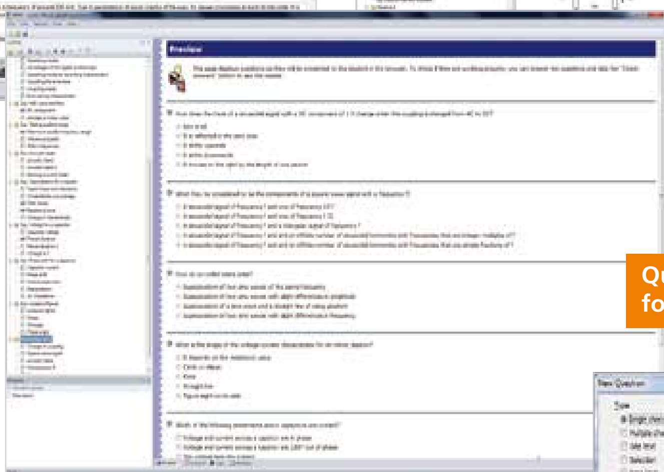


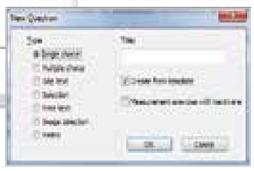
***LabSoft Editor:** LabSoft Editor allows you to create new courses or make changes to existing ones. Numerous wizards are available to guide users step by step through the necessary settings*



***LabSoft Test Creator:** LabSoft TestCreator is for creating tests, with which knowledge and practical skills can be examined at the same time.*

Question and answer database for renewable energies





***LabSoft Questioner:** In order to create individual questions, measuring exercises or test exercises, LabSoft Questioner provides a host of question templates. Tasks and questions can then be introduced into actual courses.*

SCADA Power-LAB-Software

By Supervisory Control and Data Acquisition (SCADA) we mean the real-time monitoring, control and data acquisition of technical processes. In electrical power engineering, SCADA is used to cover everything from power generation and transmission up to and including security and power usage. SCADA permits the visualisation and modification of process data. Measurement values are displayed on the screen in real-time. Control signals can be adjusted during the process. The SCADA system can also perform process control automatically. Thanks to the fact that many measurement values are recorded, future planning and economic optimization are possible. The system can also be remotely controlled via the Internet or also using local area networks (LAN).

SCADA for Power Engineering is a software designed to control and monitor power engineering systems. In the software, the system's measurement values and operating data can be displayed on existing measuring instruments in real-time. Important parameters and signals can also be controlled via the software. The measurement values and operating states of the equipment can be selected, recorded and displayed over time. Evaluation and export are also possible.

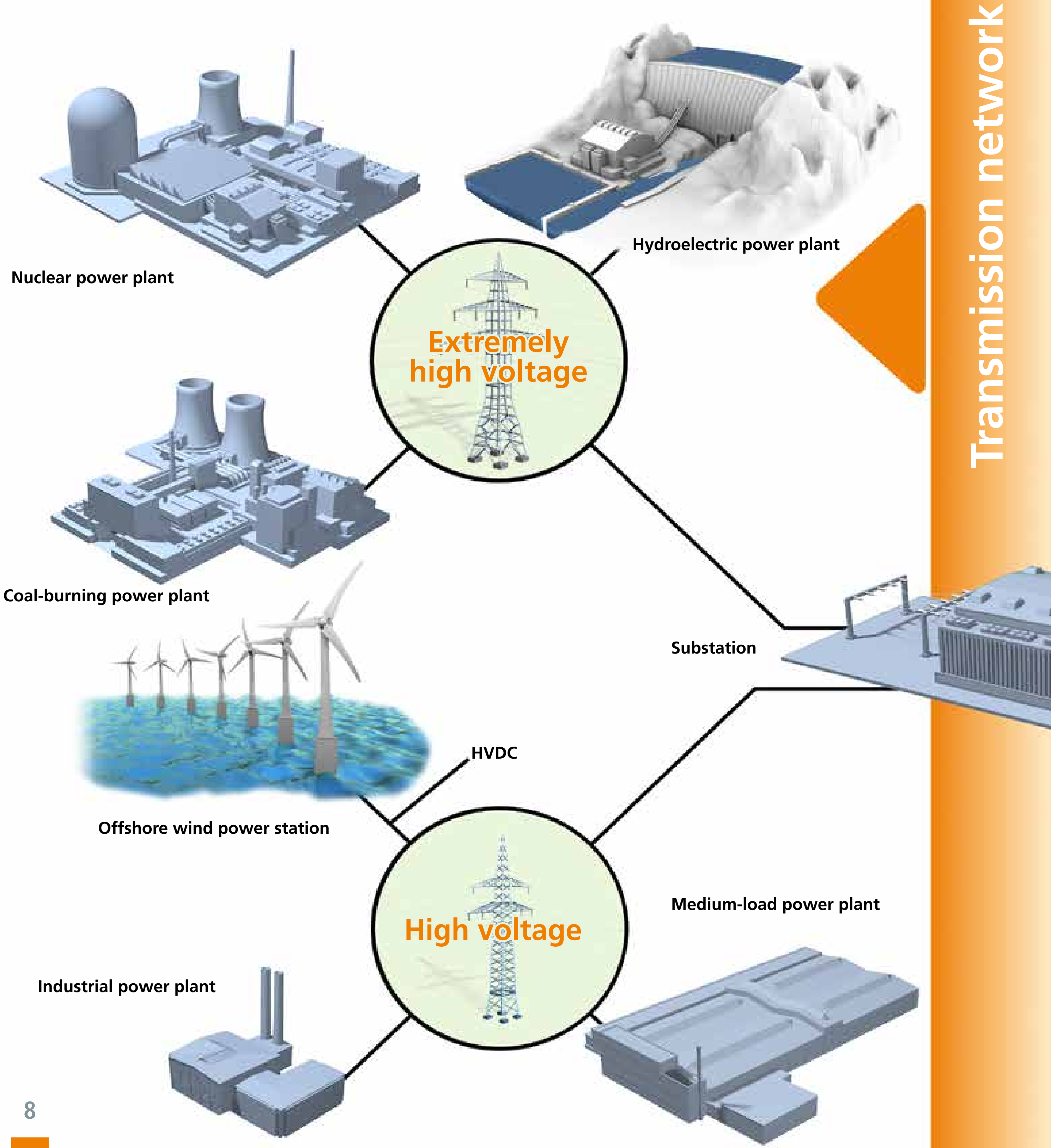
Your benefits

- SCADA software adapted for training and education
- Implementation, control and analysis of complex, intelligent grids (smart grids)
- **SCADA Designer:**
  - Symbolic layout of all equipment from Lucas-Nülle's power engineering range on a user interface
  - Standardised electronic circuit symbols
- **SCADA Viewer:**
  - School licence for observation and control of systems
  - Display and control of measurements and status from all computers on the network
- **SCADA PLC:** Integrated software PLC, programmable in compliance with IEC 61131
- **SCADA Logger:** Recording, display, evaluation and export of all values recorded in a given period
- **SCADA Panel Designer:** Design your own control panels
- **SCADA Net:**
  - The client/server concept makes it possible to remotely access systems on the smart grid from multiple student PCs at the same time.
- **Cyber Security:**
  - Access Control (Black / White List)
  - Encryption

From Power Generation Through to Consumption

The Smart Electrical Power Grid of the Future

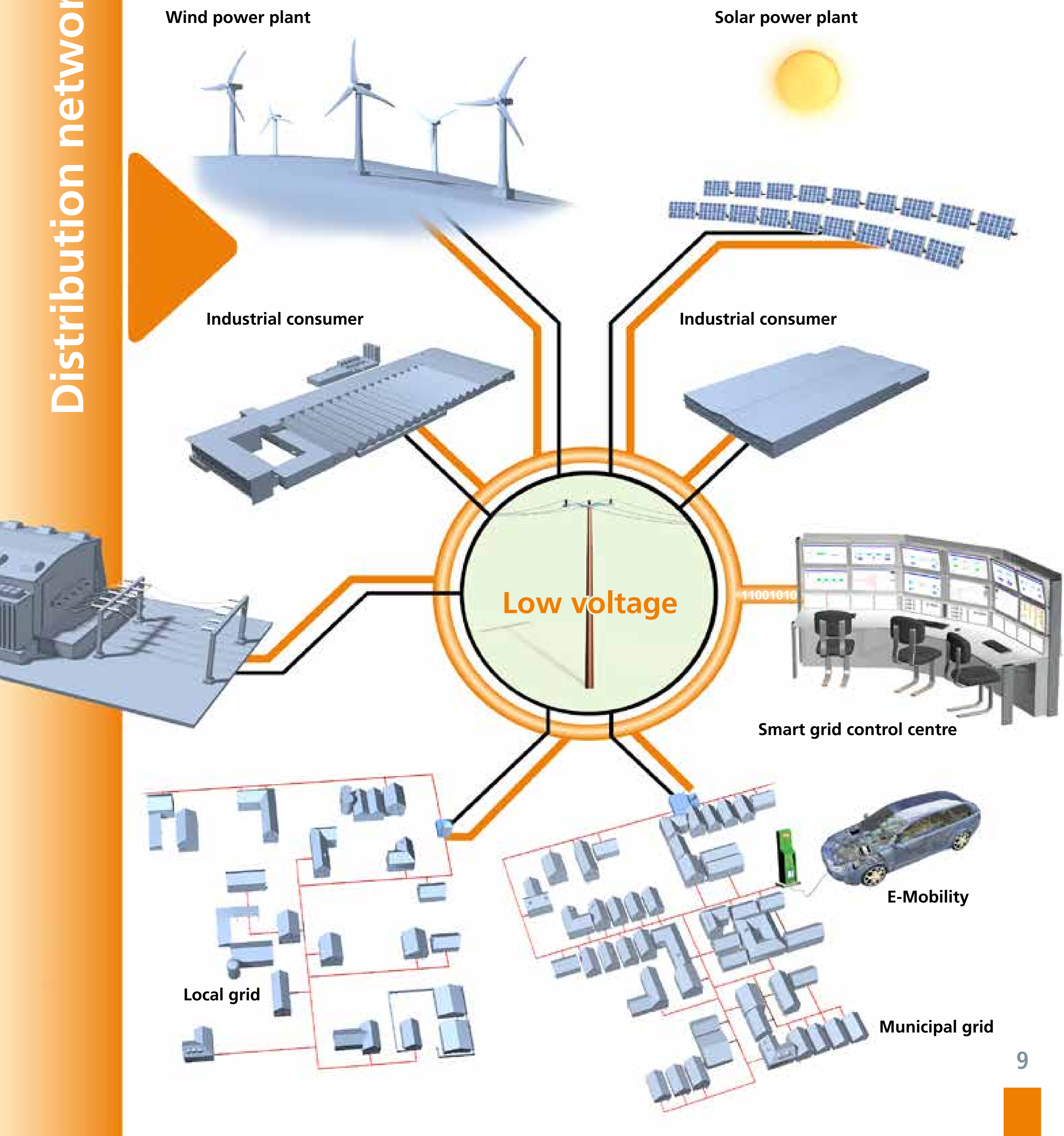
Using the Lucas-Nülle equipment sets, it is possible to model an entire power supply grid from power generation all the way to ultimate consumption.



Distribution network

You can find more on the topic of smart grids from page 106 onwards

SMART MICRO GRID

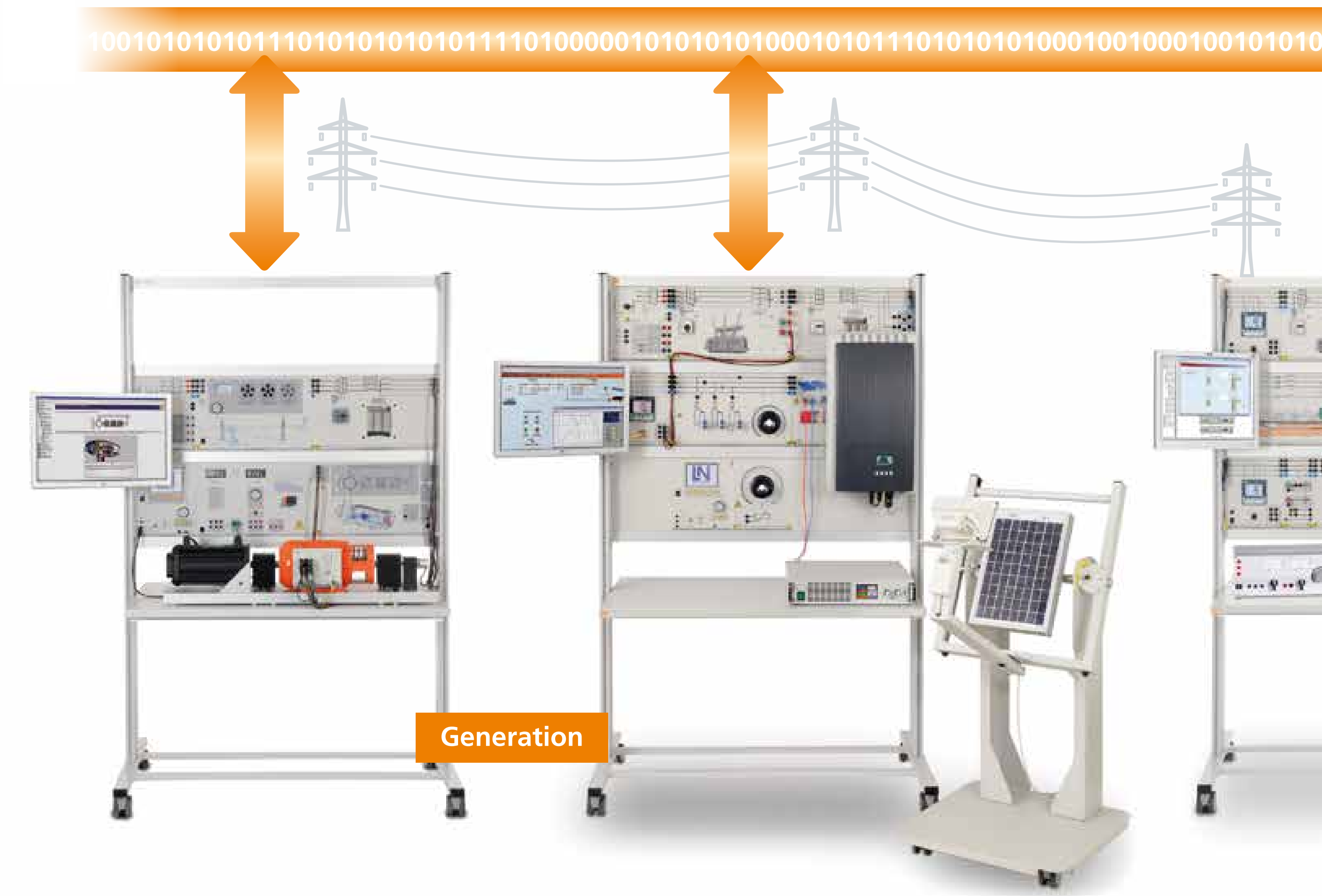


From Power Generation Through to Consumption

Networked Systems in the Power Engineering Laboratory

The smart lab

The power engineering equipment sets from Lucas-Nülle GmbH can be combined with each other as required. Accordingly, you can, for example, take the power obtained from renewable energy sources and transmit this power via a line model, use a transformer to step it up or down and distribute it to any number of consumers using the double busbar. Additionally, the bus systems of the measurement and protective equipment can all be interconnected, centrally evaluated and controlled using our SCADA Power-LAB software. It makes it safe and easy to design and investigate intelligent power grids in the lab.



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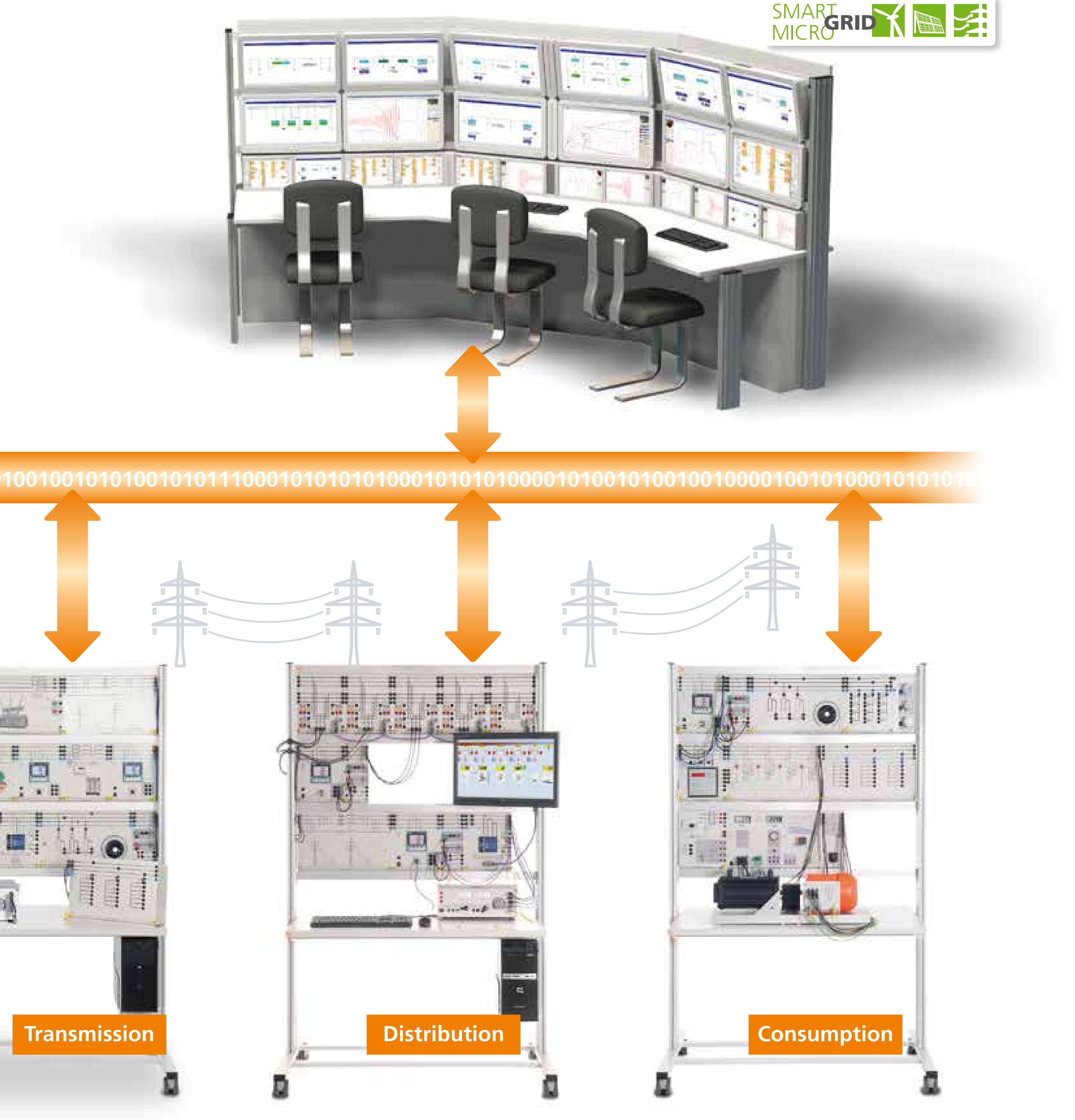


The Entire System at a Glance

eCO2Train

Protection of power engineering facilities

SCADA EGP

Generator protection

- Generator-differential protection
- Overcurrent time protection
- Unbalanced load protection
- Reverse-power protection
- Over/undervoltage protection
- Stator-earth fault protection
- Rotor-earth fault protection

SCADA ETP

Transformer protection

- Transformer-differential protection
- Time overcurrent protection

Investigations on power engineering facilities

SCADA EUG

Power generation

- Three-phase synchronous generators
- Synchronisation circuits
- Automatic power factor and power control

Renewable power generation

- Wind power
- Photovoltaics
- Fuel cells

UNITRAIN SYSTEM

SCADA EUT

Transformers

- Transformer operating at no-load and with short circuit
- Transformer with ohmic, inductive and capacitive load
- Parallel operation of transformers
- Current distribution for various vector groups

UNITRAIN SYSTEM

Fundamentals of electrical engineering

Basics of electrical engineering

- DC technology
- AC technology
- Three-phase technology
- Magnetism/electromagnetism
- Measurements with the multimeter

UNITRAIN SYSTEM

Power grids and grid models

- Transient processes in DC and AC grids
- DC power grids

UNITRAIN SYSTEM

SCADA ELP

Line protection

- Over/undervoltage protection
- Directional protection
- Overcurrent time protection
- Earth-fault protection
- Protection of parallel lines
- Distance protection

SCADA EDP

Busbar protection

- Overcurrent protection for double busbars

SCADA ECP

Protection for electrical loads

- Protection for electrical machines
- Motor management relays

SCADA EUL

Power transmission

- Investigations on three-phase lines
- Parallel lines
- Lines with earth-fault compensation
- Transmission systems with synchronous generator
- Combined networks of cables and lines
- High-voltage direct current transmission (HVDC)

SCADA EPD

Power distribution

- Three-phase double busbar system
- Manually operated busbar change
- Automatic busbar change with PC

SCADA EUC

Power consumption

- Complex loads
- Reactive power compensation
- Power consumption measurement
- Peak load monitoring
- Energy management

EUB

Current and voltage transformers

- Current transformer for protective equipment
- Voltage transformer for protective equipment

Smart grid / micrgrid

- Renewable Energies in a smart grid
- Combination and constrol of all systems
- SCADA Software
- Intelligent energy management: coordination of energy generation and consumption

SMART MICRO GRID

More Than Just a Training System

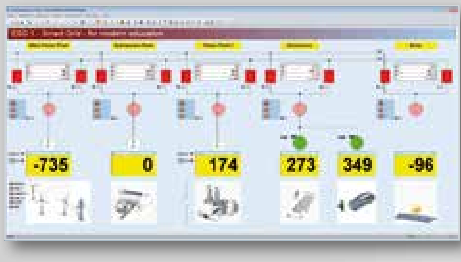
The Power Engineering Lab is a Complete Solution

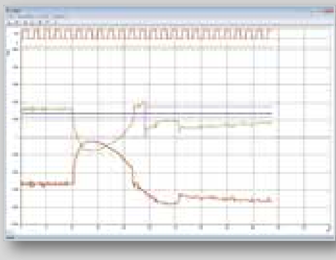
Modern training media are used to graphically present complex learning material

**Renewable energies:
Wind power, fuel cells, photovoltaics**

eCO$_2$Train

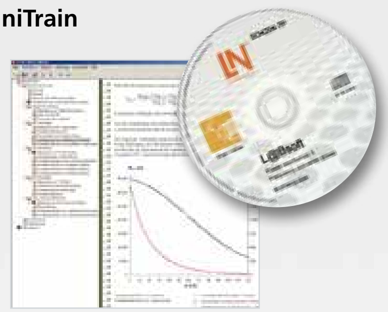
"Smart grid": monitor, measure and control the entire power flow using the SCADA system

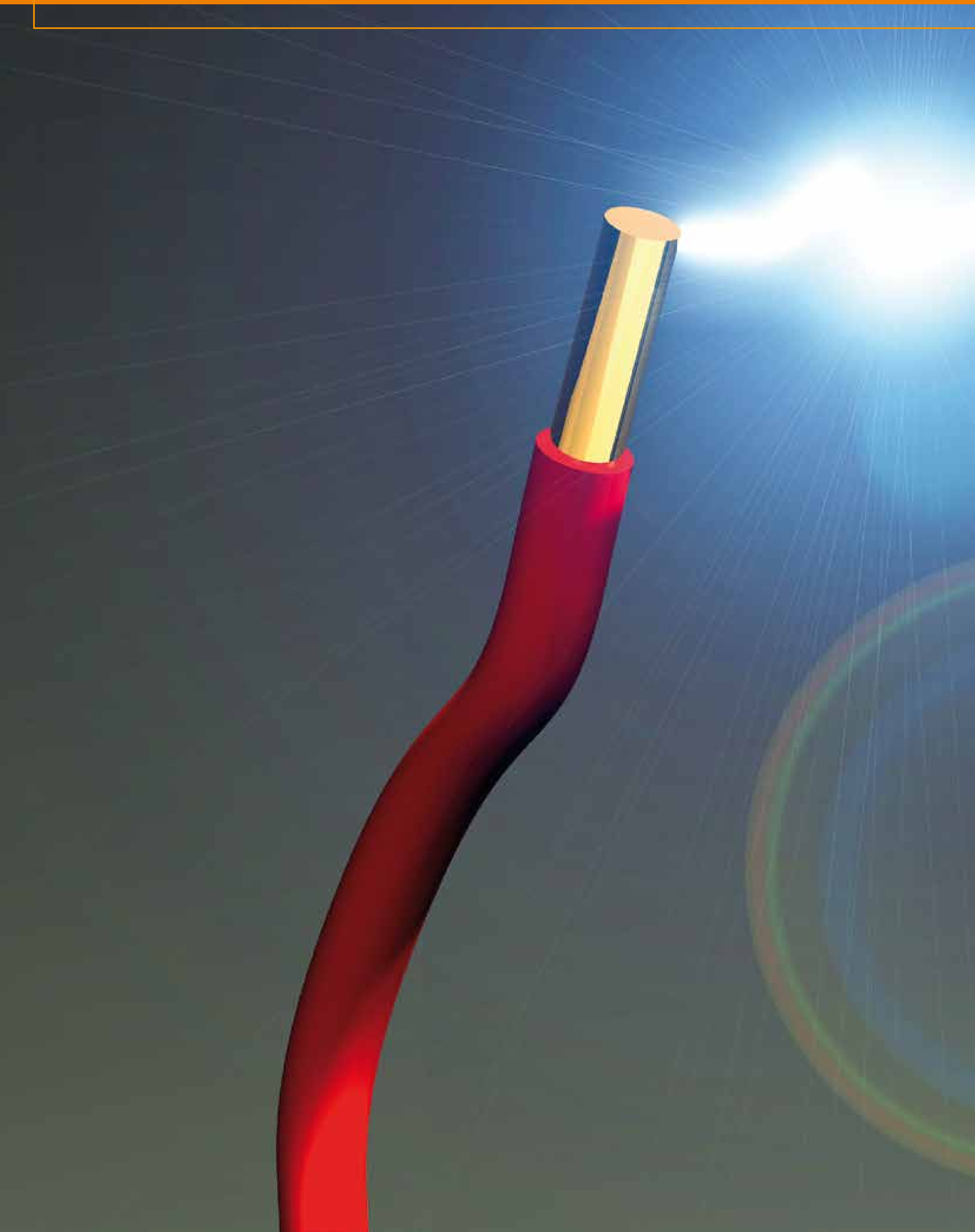




Complete solutions for electrical power engineering: from power generation, transmission and distribution through to consumption – it's all covered.

Multimedia-based transfer of know-how using UniTrain





Fundamentals of Power Engineering

Fundamentals of Power Engineering

Multimedia-based and Practice-oriented Introduction to Power Engineering

Using the multimedia-based experiment and training system UniTrain, the student is guided through experiments and theoretical sections accompanied by clearly structured course software which is enhanced by texts, graphics, animations and progress tests. In addition to the learning software, the course comes with a set of experiment cards on which practical assignments are performed.

With the aid of numerous experiments and animations, the UniTrain multimedia course gives the student insight into the latest important issues relating to power engineering. The fundamentals of DC, AC and three-phase technology as well as processes in distribution networks are some of the subjects dealt with in the various courses. Typical processes that occur in the generation and distribution of electrical power receive particularly close attention and are reproduced in the experiments using safe extra-low voltages.

Your benefits

- System trains theory and practice at same time and location
- Student motivation boosted thanks to PC and new media
- Structured course design leads to rapid learning success
- Quick understanding achieved through animation-backed theory
- Hands-on practical skill through autonomous experimenting
- Continuous feedback provided by comprehension questions and tests
- Guided fault finding using integrated fault simulator
- Safe due to the use of protective extra-low voltage
- Very wide selection of courses
- Sample solutions for the instructor

UniTrain system

- Comprehensive, portable laboratory
- Multimedia-based courses
- High-tech measurement and control interface
- Trains theory and practice at same time and location

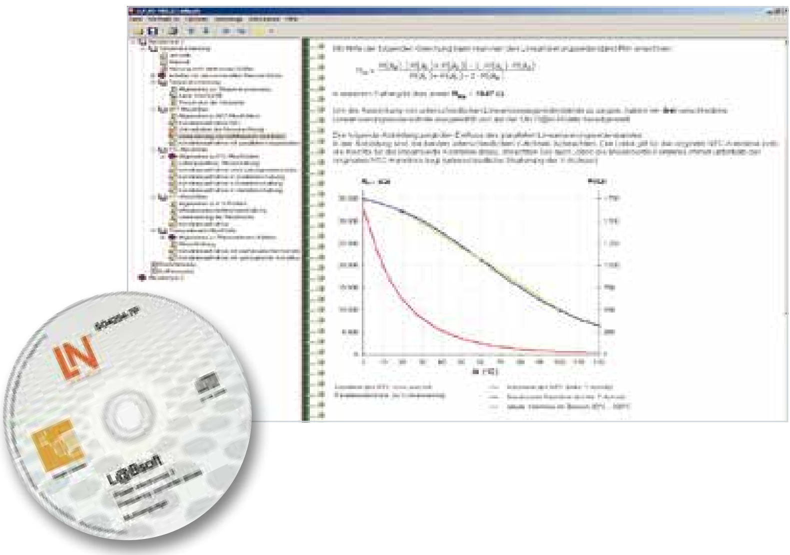
UNITRAIN SYSTEM

Integrated meters and power supply units

- Multimeter, ammeter, voltmeter
- 2-channel storage oscilloscope
- Function and signal generator
- Three-fold power supply unit for AC and DC
- Three-phase power supply unit
- ... and many more instruments

LabSoft learning and experimenting software

- Wide selection of courses
- Comprehensive background theory
- Animations
- Interactive experiments with instruction guide
- Free navigation
- Documentation of measurement results
- Tests available in the language of your choice



DC Technology

Current, Voltage and Resistance Circuitry

Current, voltage, resistance – learning the hands-on, practical side of the fundamentals of electrical engineering. This colourful course covers the basic laws of electrical engineering which are explored in numerous and easily understood experiments, animations and texts.

UNITRAIN SYSTEM

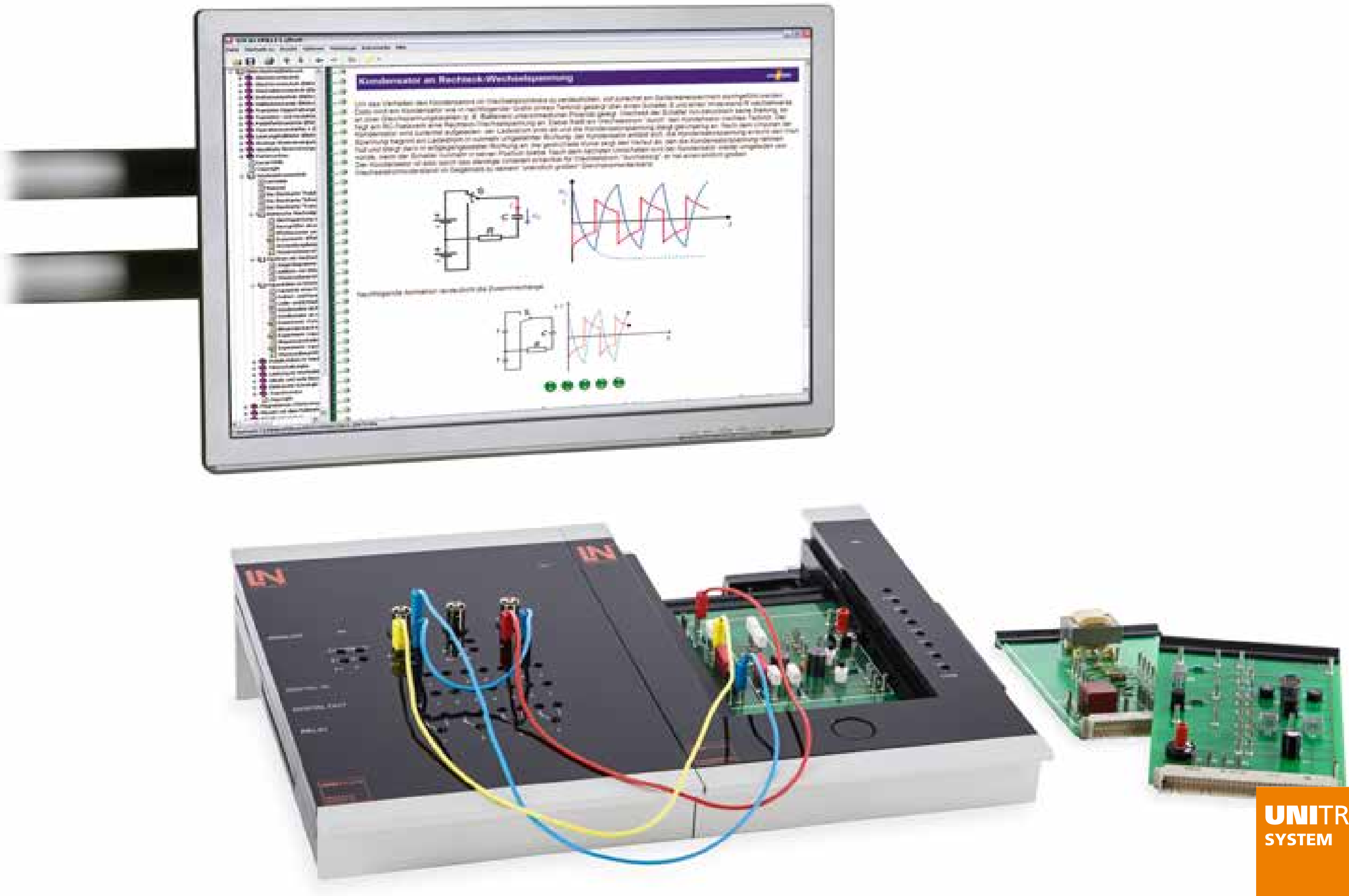
Training contents

- Basic concepts: electrical charge, electrical field, current, voltage, resistance and power
- How to work with power sources and measuring instruments
- Experiment-based verification of Ohm's and Kirchoff's laws
- Measurements on series and parallel circuits as well as voltage dividers
- Recording the characteristics of variable resistors (LDR, NTC, PTC, VDR)
- Investigating the coil and capacitor inside a DC circuit
- Troubleshooting
- Course duration 8 h approx. (fault finding 1.5 h approx.)

AC Technology

Inductance, Capacitance, Oscillating Circuit/Transformer

How do coils and capacitors respond when an AC current is applied? What is an oscillating circuit and how does a transformer work?



UNITRAIN SYSTEM

Training contents

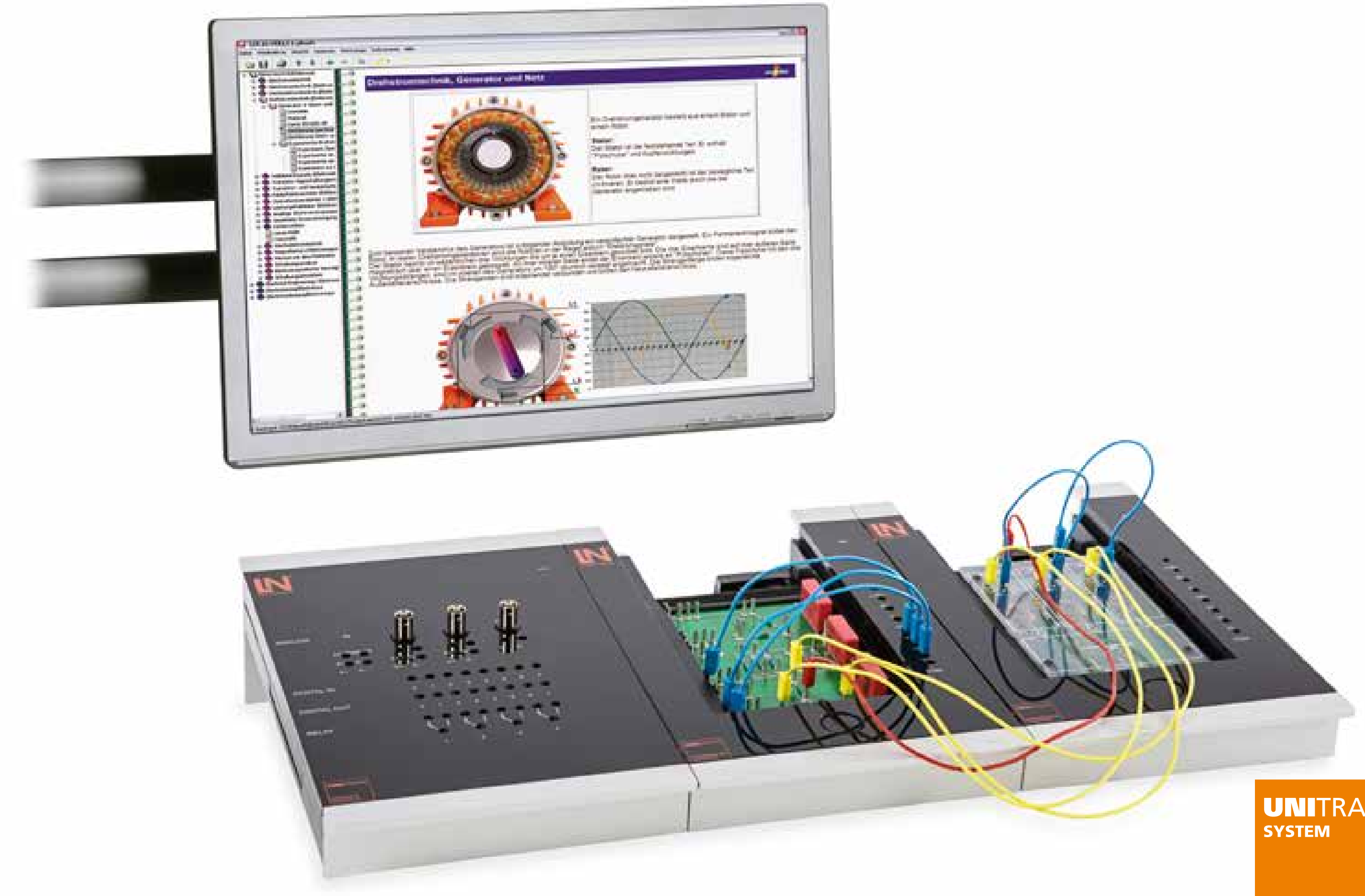
- Parameters of periodic and sinusoidal signals
- How to work with vector diagrams
- Determine reactance of coils and capacitors using experiments
- How to explain active, reactive and apparent power
- Determine the frequency response of simple filter circuits
- Electrical oscillating circuit: resonance, quality, bandwidth and cut-off frequency
- Measurement of the frequency response of series and parallel resonant circuits
- Load, no-load and short-circuit measurements
- Frequency response of transformers and transducers
- Troubleshooting
- Course duration 8 h approx. (fault finding 1 h approx.)

UniTrain course SO4204-4F

Three-phase Technology

Star-delta Circuit Configuration, Three-phase Generator

Three-phase systems are of critical importance in power engineering and drive technology, both in terms of generation and the transmission of electrical power as well as the operation of high-powered industrial machinery.



UNITRAIN SYSTEM

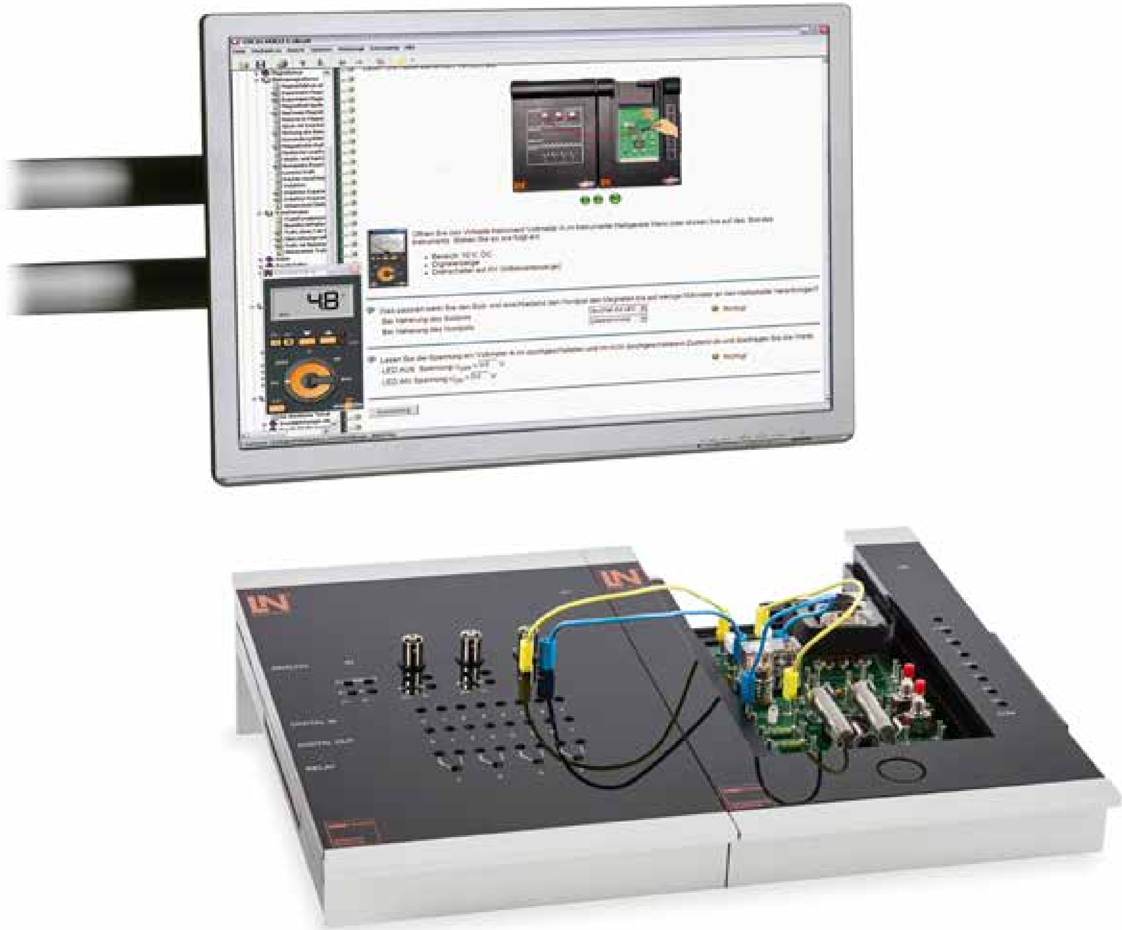
Training contents

- Measurements of phase-to-phase and line-to-line variables on the three-phase electricity supply
- Experiment-based determination of laws between line-to-line and phase-to-phase voltages
- Ohmic and capacitive loads in star and delta circuit configuration
- Phase-shift between line and phase voltage
- Measurement of the compensation currents in the neutral conductor
- Effects of breaks in the neutral conductor
- Current and voltage measurements of balanced and unbalanced loads
- Power measurement at a three-phase load
- Course duration 4 h approx.

Magnetism / Electromagnetism

Magnetic field, induction, components

Magnetism and electricity are very closely related. Many components in electrical engineering take advantage of electromagnetic effects.



UNITRAIN SYSTEM

Training contents

- Magnetism: magnetic poles, magnetic field, field lines and field intensity
- Hard and soft magnetic materials, hysteresis
- Investigation of the magnetic field of a current carrying conductor
- Investigation of the magnetic field of an inductor (air-core coil, coil with core)
- Electromagnetic induction and Lorentz force
- Design and operation of a transformer
- Investigation of a transformer operating under various loads
- Design and function of electromagnetic components: relays, reed switches, Hall-type switches
- Investigation of application circuits
- Course duration 4 h approx.

Measurements with the Multimeter

Current Measurement, Voltage Measurement, Resistors and Diodes

Taking measurements correctly and working safely – in this course, training involves how to work safely with a conventional multimeter on the basis of numerous measurement exercises and animations.

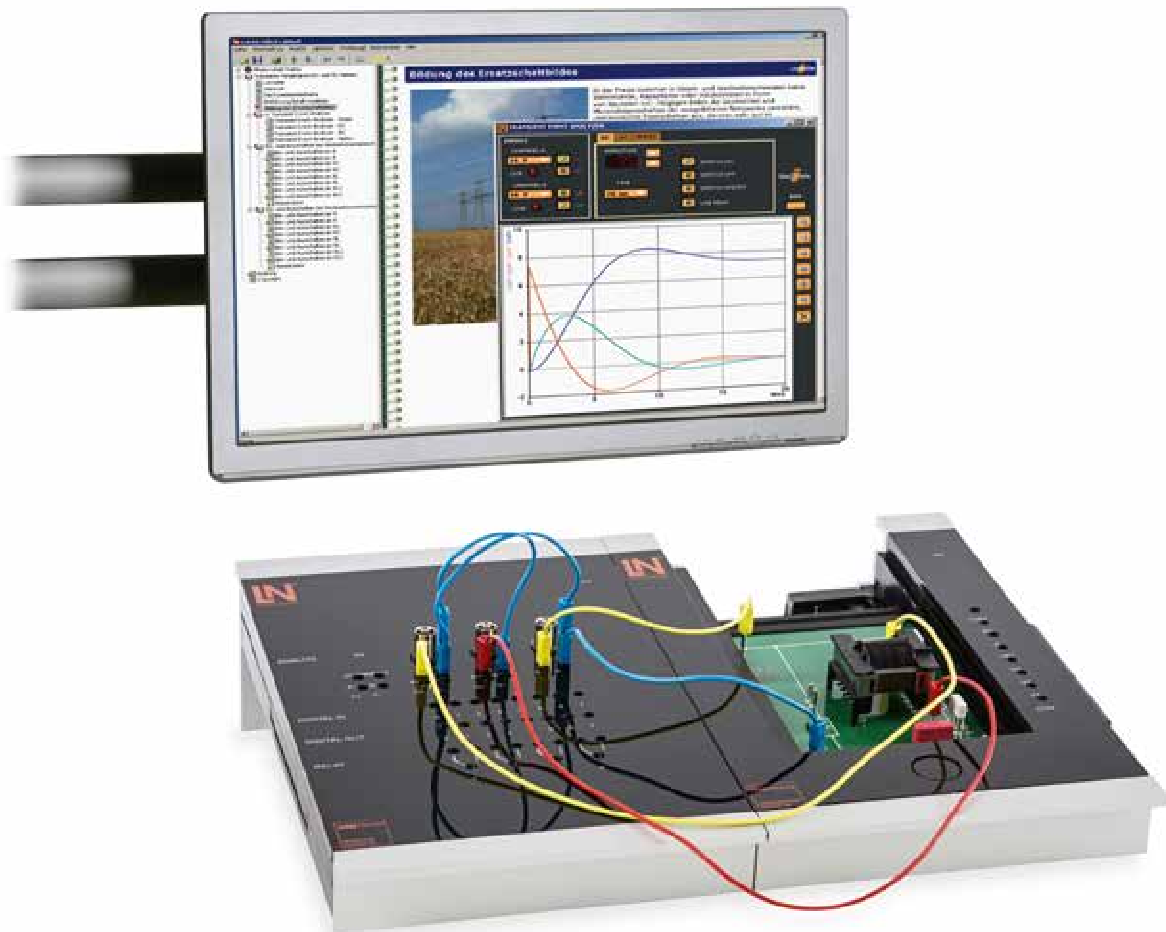
Training contents

- Familiarisation with the operating elements of the multimeter
- Potential risks when measuring electrical circuits
- Measuring electrical DC and AC voltages with the multimeter
- Measuring electrical DC and AC currents with the multimeter
- Measuring resistors and diodes
- Zero balance and continuity testing
- Measurement range adjustment
- Identification of potential fault sources during measurements
- Determination of components in an unspecified circuit using current and voltage measurements
- Course duration 3 h approx.

Power Grids and Grid Models

Transient Processes in DC and AC Power Grids

In existing low-, medium- and high-voltage grids, there are two different processes that arise: stationary (constant loads) and transient phenomena. These typical transient processes, which require special consideration during the generation and distribution of electrical power, are simulated and dealt with in experiments run with protective extra-low voltages.



UNITRAIN SYSTEM

Training contents

- Learning about the significance of switching processes in power grids
- Accessing the effects (hazards) of switching processes in power grids
- Experiment-based investigation of the current and voltage characteristics in response to switching on a DC voltage
- Investigation of the influence of various loads (R, L, C) on the signal characteristic
- Experiment-based investigation of the current and voltage characteristics in response to switching on an AC voltage
- Investigation of the influence of the on and off switching time
- Signal characteristic measurements at various switch-off times
- Determination of the optimum switching time
- Analysis of on and off switching processes and their effects on complex loads (R, L, C) at different switching times
- Course duration 3.5 h approx.

Current and Voltage Transformers

Current Transformer for Protective Equipment

A wide spectrum of current and voltage transformers are used for various requirements in electrical power engineering. The experiments include a practical hands-on investigation of transfer response, over-current factor, absolute and phase angle error, as, for example, under varying loads. In addition to this, standard operation requirements, short-circuit and asymmetrical faults can also be explored.

Sample experiment "Current transformer" EUB 1

Training contents

- Secondary transformer current as a function of the primary current
- Effect of the load on current ratio error
- Check rated overcurrent factor
- Transformer circuit in three-wire system
- Transformer circuit in four-wire system
- Determine zero residual current

Voltage Transformer for Protective Equipment

The protection of system facilities and components is not only dependent on selective protection equipment but also on the detection and measurement of the lowest fault currents and voltages. Various types of measurement circuits have to be used for different star-point circuit configurations in order to correctly detect and localise potential fault types.

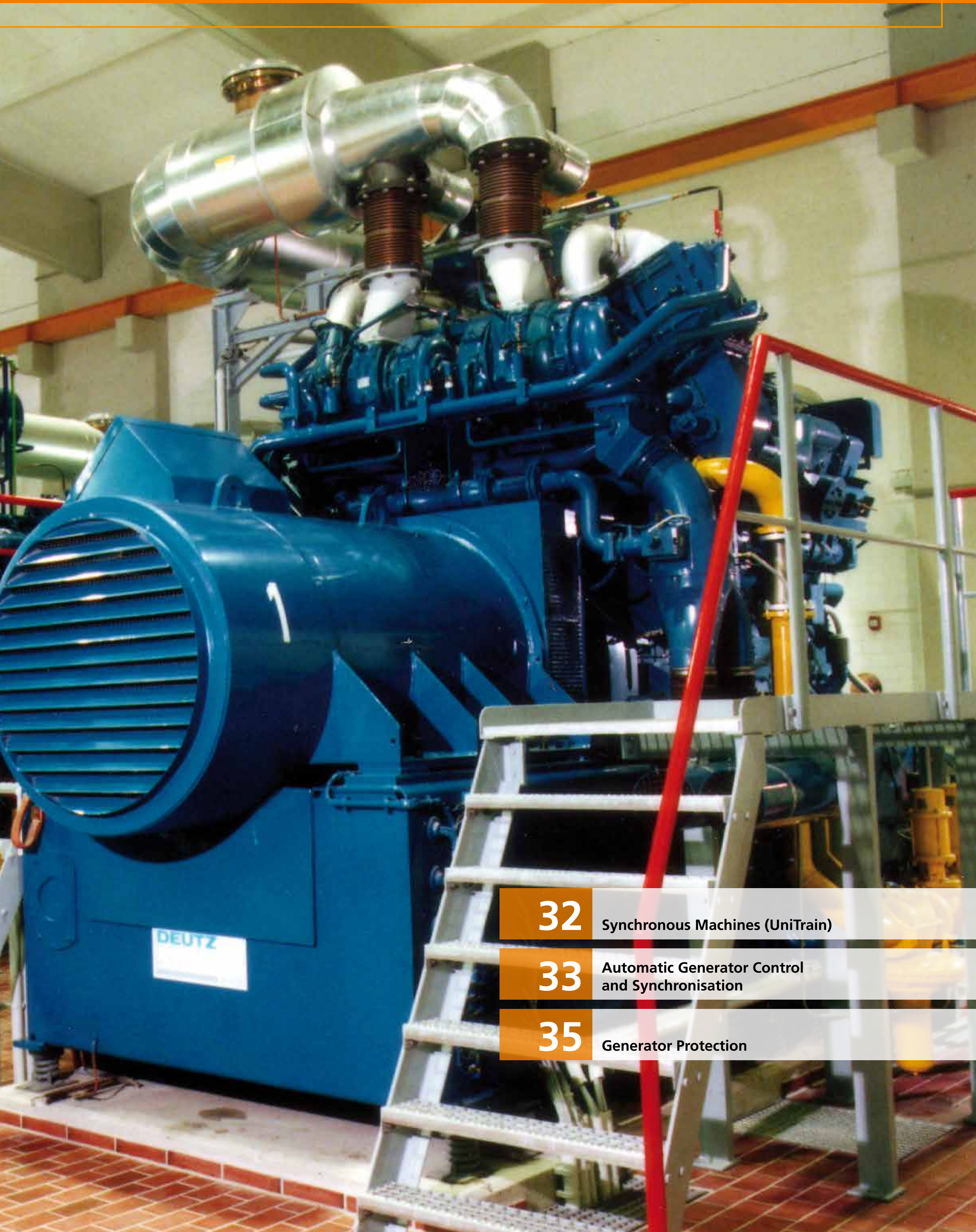
Sample experiment "Voltage transformer" EUB 2

Training contents

- Voltage transformer characteristics
- Calculation of voltage faults and class of accuracy
- Effect of loads on the transformation ratio
- Three-phase voltage transformer in a healthy grid
- Three-phase voltage transformer in a grid with earth-fault on the primary side

Source: Woodward SEG

Power Generation



Power Generation

Three-phase synchronous generators

In addition to the basic experiments on three-phase synchronous generators, the experiments in this area also cover manually-operated and automatic synchronisation circuits as well as automatic power factor control (cos-phi control) and power control. For that reason, this module can be used to simulate both on-grid and off-grid power plant operation. Furthermore, generators need effective protection against internal and external faults. The deployment of a variety of protective equipment is a prerequisite for this.

Three-phase synchronous generators
Electrical power is primarily generated using three-phase generators. This applies to both power stations as well as power generating units and wind generators.
These generators must be protected against internal and external faults using a wide range of protective devices.

Source: Woodward SEG

Servo machine test bench
An essential component of power engineering equipment sets is the servo machine test bench – a complete testing system designed for the examination of electrical machines and generators. It consists of the digital control unit, a servo drive and the ActiveServo software package. The system combines state-of-the-art technology with simple operation. In addition to the drive and brake, working machine models can also be emulated realistically. As such, machines, generators and drives can be investigated under industrial-like conditions inside the laboratory.

Training systems
Our training systems cover the following topic areas:

- UniTrain three-phase synchronous generators
- "Automatic generator control and synchronisation" training panel system
- "Generator protection" training panel system

Synchronous Machines

Slip-ring Rotor Machine, Synchronous Machine, Reluctance Machine

Reluctance motors are the motors of the future. Today, three-phase machines with synchronous and slip-ring rotors are already in widespread use.

UNITRAIN SYSTEM

Training contents

- Explanation of the technology and its practical applications
- Exploration of the basic physics needed to understand the technology
- Starting machines with start resistors as well as variable frequency
- Open-loop speed control
- Conduct various experiments on:
  - Connection of motors with slip-ring rotors
  - Influence of open or wired rotor windings
  - Effect of different exciter voltages
- Course duration 5 h approx.

Automatic Generator Control and Synchronisation

Manually operated Synchronising Circuits

Electrical power is primarily generated by three-phase generators. This applies for conventional steam turbine and hydroelectric power stations as well as for power and wind generators. In addition to performing basic experiments on the three-phase synchronous generator, other experiments cover the topic of manually operated synchronising circuits.

Sample experiment "Manually operated synchronising circuits" EUG 1

Training contents

- "Dark" synchronising circuit
- "Light" synchronising circuit
- "Cyclic" synchronising circuit
- Active power generation
- Inductive reactive power generation
- Capacitive reactive power generation

Automatic Generator Control and Synchronisation

See page 115, Pumped Storage Hydroelectricity (equipment set EUG 3)

Automatic synchronising circuits, automatic power control and power factor control

Besides the experiments on automatic synchronisation circuits, there are also experiments included on automatic power factor (cos-phi) and power regulation. Consequently, a power station can be simulated in off-grid and on-grid operation.

Sample experiment "Automatic synchronising circuits" EUG 2

Training contents

Automatic synchroniser circuits

- Putting into operation and parameterisation of the automation unit
- Synchronisation in test mode
- Synchronisation to the real power grid
- Response of the automation unit to faulty programming

Automatic power factor control

- Parameterisation of the automatic cos-phi controller
- Synchronisation of the generator to the power grid
- Cos-phi control of the synchronous generator
- Cos-phi control of the power grid

Automatic power control

- Parameterisation of the automatic power controller
- Synchronisation of the generator to the power grid
- Response of power controller to change in control variable and disturbance variable
- Power controller sensitivity and direction of action

Generator Protection

Multifunction Relays

Effective protection of generators against internal and external faults requires that a wide variety of protective devices be deployed. The time overcurrent protection constitutes the reserve protection for the generator and can also be used for the detection of external faults, such as short circuits and overload, for example. Earth-fault occurrences are detected with the stator-earth fault protection. The investigation of reverse power and unbalanced load protection as well as overvoltage/undervoltage protection concludes the experiment series titled "EGP" on generator protection.

Sample experiment "Generator protection" EGP 1

Training contents

Time overcurrent protection
- Operating response and release response for single-pole and three-pole faults
- Determining the tripping times

Unbalanced load protection
- Operating and release response to unbalanced load
- Determining the reset ratio and the tripping times
- Determining the relay characteristic TA = f(unbalance)

Reverse power protection
- Synchronisation of the generator to the power grid
- Detection and disabling of the generator in the case of reverse power flow

Overvoltage and undervoltage protection
- Reactions to phase failure
- Detection of starting and tripping times

Stator-earth fault protection
- Detection of system voltages under normal operating conditions or stator-earth fault occurrence
- Measurement of tripping times
- Calculation of the earth-fault current

Generator Protection

Generator Differential Protection

Generator differential protection which detects internal faults such as short-circuit, turn-to-turn and winding-to-frame shorts or double earth faults, serves as primary protection.

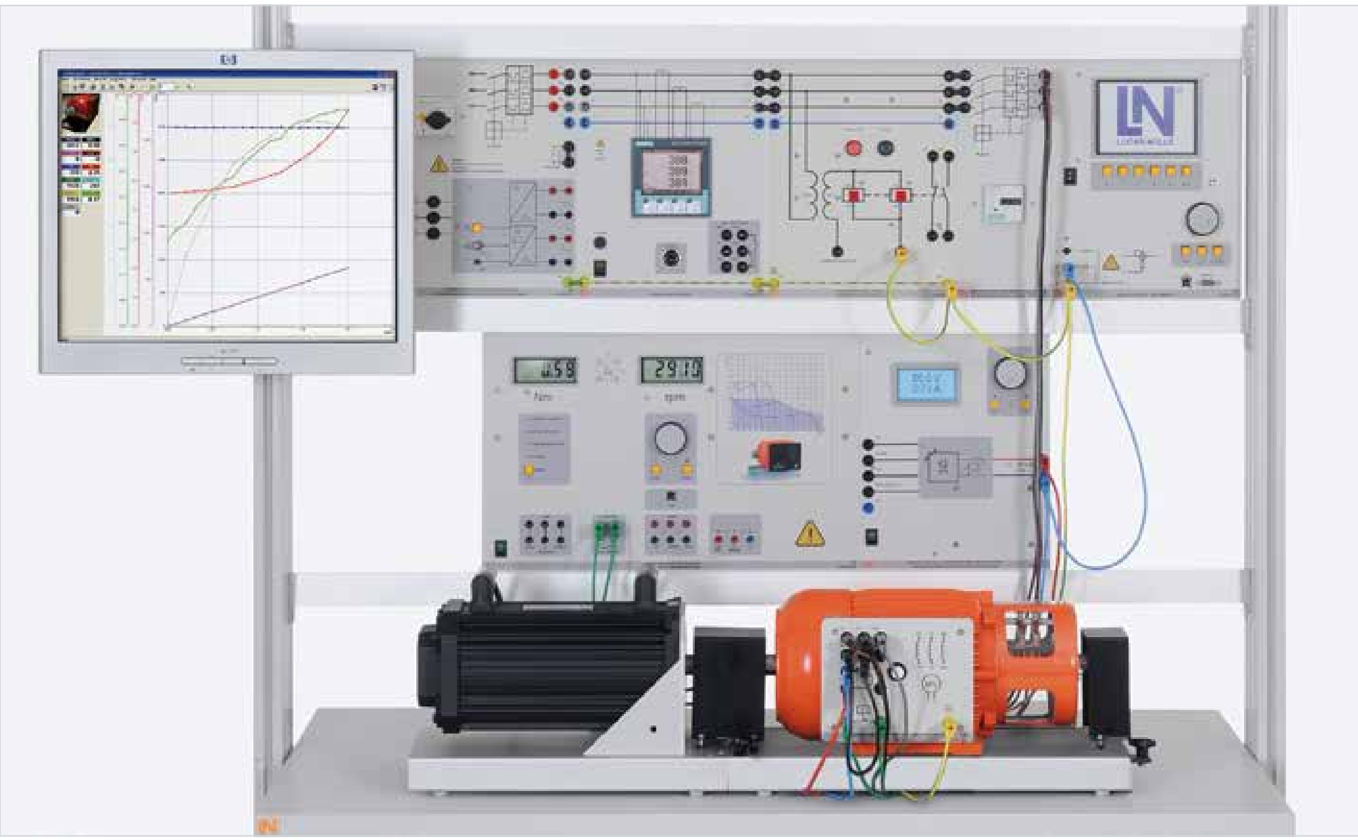
"Generator differential protection" EGP 2

Training contents

- Calculating protection operating values
- Fault recognition within the protection range
- Testing tripping and reset for faults occurring inside and outside the protection range
- Disconnection and de-excitation of the generator
- Measurement of the operating (pick-up) currents of the protection device for symmetrical and asymmetrical faults
- Comparison of measured values to set values

Rotor Earth-fault Protection

The rotor earth-fault protection is used to determine earth faults in the exciter circuit of synchronous machines.



„Generator protection - rotor earth-fault protection" EGP 3

Training contents

- Putting the synchronous generator into operation
- Investigation of normal operating conditions and rotor earth-fault occurrences
- Measurement of the rotor earth-fault current
- Rotor earth-fault relay during earth-fault operation:
  - Connection and testing of the earth-fault relay
  - Setting different rotor earth faults
  - Testing the fault signal and disconnection

Renewable Power Generation

Renewable Power Generation

Inexhaustible, Sustainable, Real – the Future is Green

The move away from coal, oil and nuclear power to renewable forms of energy is gaining momentum. Today, technology has evolved to a point where solar energy, wind power, hydrogen fuel and biomass can be exploited as environmentally friendly energy sources. In order to sustain this trend, the search is on to find and train well-qualified technical staff worldwide.
Technologies are continuing to change rapidly, as are related requirements for training. Lucas-Nülle has the training systems to meet increasingly complex educational demands.

Sunny prospects with photovoltaics

- Abu Dhabi has announced it will invest about two billion US dollars in technology for manufacturing thin-film photovoltaic modules in Masdar.
- The USA's largest solar power plant with a rated output of 25 megawatts is being established in Silicon Valley.
- Photovoltaic facilities capable of generating a total of five gigawatts have already been realized in Germany. This output is equivalent to that of five modern power plant units. By 2020, photovoltaic power generation capacity is to be increased gradually to 40 GW.

A clean future with wind energy

- Forecast for Germany: By 2030, 25% of electricity will be produced by means of wind power.
- A 3.0-megawatt wind farm annually saves 13,000 barrels of oil or 10,000 tons of CO_2.

Fuel cells – Long term energy storage elements

- Used in zero-emission vehicles
- Used widely as a standby power source
- Used by co-generation units

Photovoltaics

Sunny prospects with the photovoltaics course

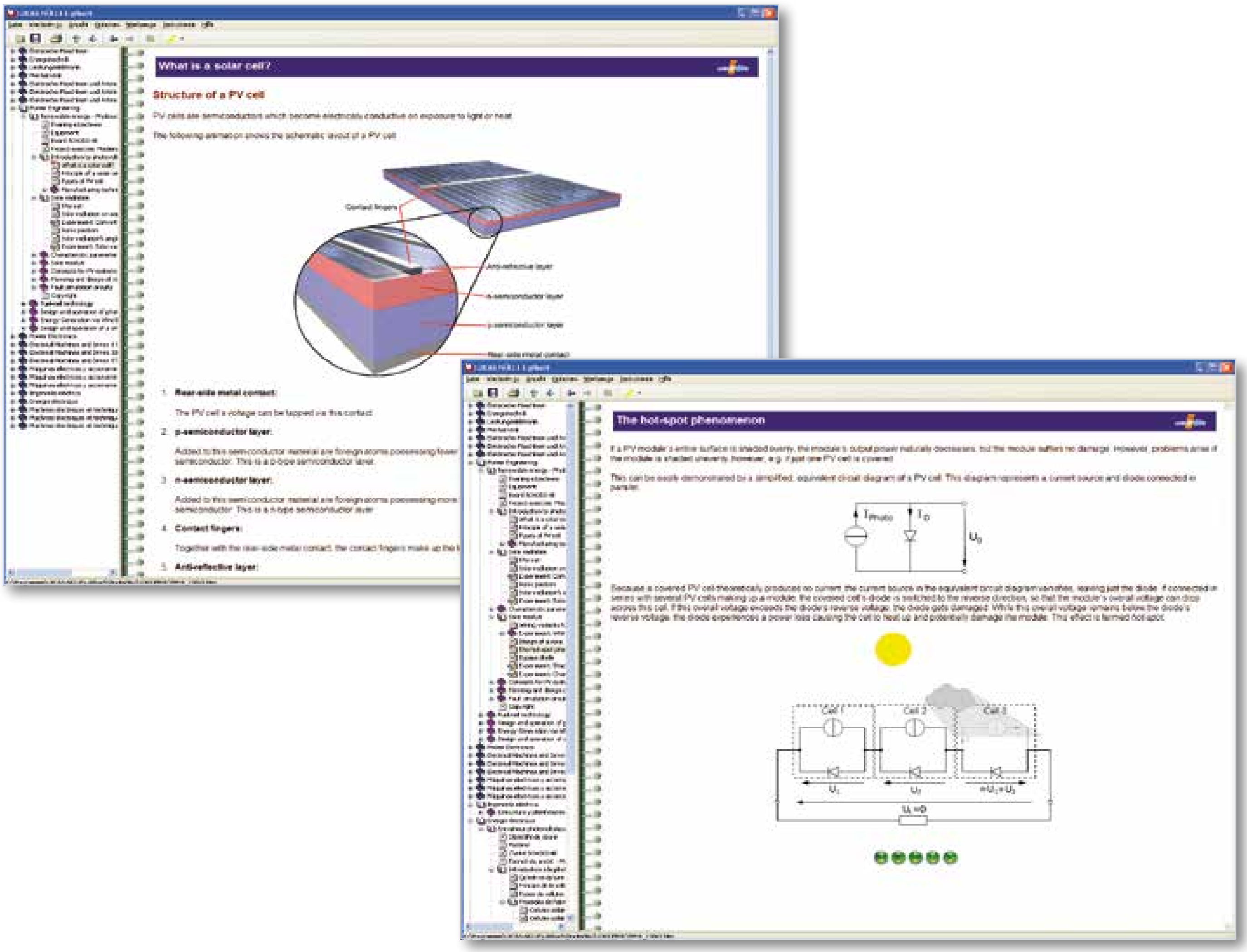
In times of soaring energy costs and increased environmental awareness, photovoltaic technology constitutes a very interesting alternative to traditional power generation. With the photovoltaics course, you can not only research the fundamentals of solar cells, but also simulate operation of a photovoltaic system in direct or storage mode.

UNITRAIN SYSTEM

Training contents

- Functions and operating principles of solar cells
- Recording the characteristics of a solar module
- Dependency of a solar module's current and voltage on temperature, irradiance and angle of incidence
- Series, parallel and other types of circuit for solar cells
- Manufacture of solar cells
- Various types of solar cell
- Design of a photovoltaic battery
- Various types of solar plant
- Setup of an off-grid power system with rechargeable solar cells

Multimedia course consolidates the experiment



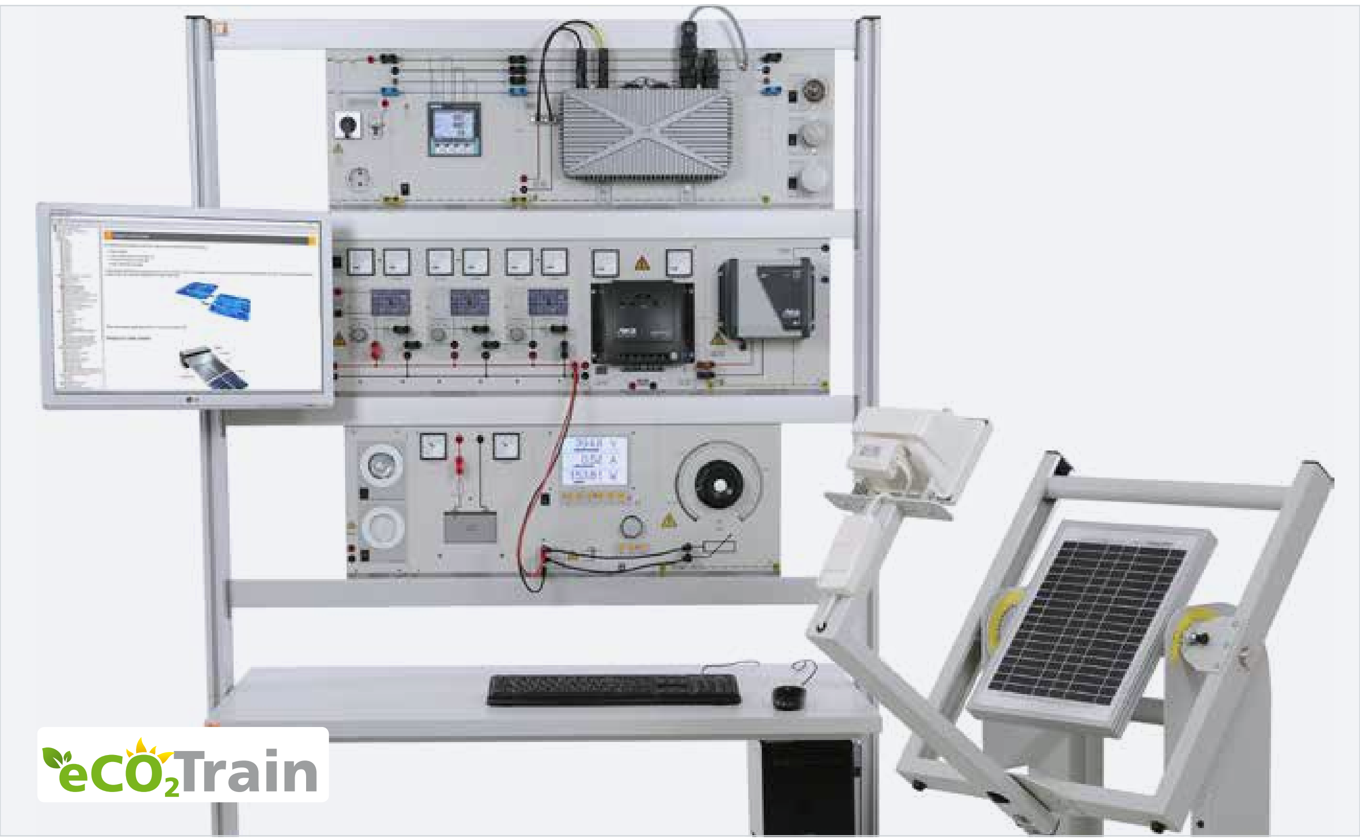
Your benefits

- Theoretical knowledge and practical know-how are conveyed using the UniTrain multimedia course
- Complete equipment set including all relevant components
- PC-supported evaluation of measurement data
- System operates with 12 V safe extra-low voltage
- System supports fault simulation
- Course duration 4.5 h approx.

Advanced Photovoltaics

Project Work with Industrial Components

The training system permits realistic simulation of paths taken by the sun. Emulators make it possible to conduct practical experiments in the laboratory without the sun.
Permitting PC-supported evaluation of measurement data, the advanced photovoltaics multimedia course is designed to convey both theoretical information and practical know-how.



Sample experiment "Advanced photovoltaics" EPH 2

Training contents

Investigating solar modules

- Testing the optimum alignment of solar modules
- Recording the characteristics of solar modules
- Investigating response to partial shading
- Investigating how bypass diodes operate
- Learning about various types of wiring for solar modules

Setting up photovoltaic systems for off-grid operation

- Installing photovoltaic systems
- Setting up and testing an off-grid PV system in direct mode
- Setting up and testing an off-grid PV system in storage mode
- Setting up and testing an off-grid PV system for generating 230-V alternating voltage

Setting up photovoltaic systems for grid-parallel operation

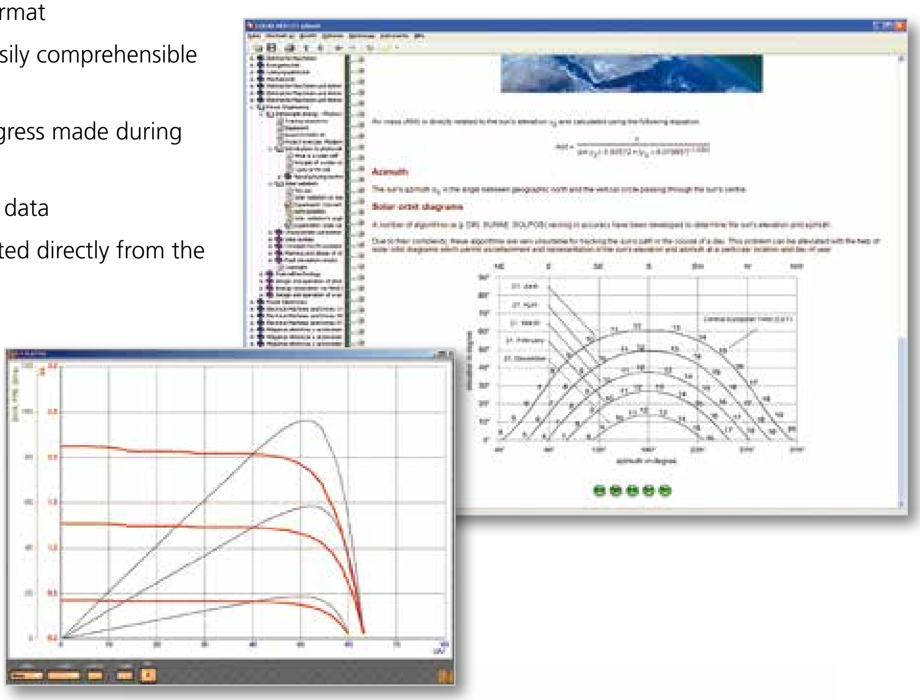
- Installing, setting up and testing a PV system with network feed
- Measuring the energy produced by a PV system
- Determining a grid-connected inverter's efficiency
- Investigating a PV system's response to a power outage on the grid

Advanced Photovoltaics

A Little Sunshine for your Lab

Interactive Lab Assistant

- Step-by-step instructions in multimedia format
- Explanation of physical principles using easily comprehensible animations
- Quiz and assessment tools for testing progress made during the course
- PC-supported evaluation of measurement data
- Virtual measuring instruments can be started directly from the experiment manual



Solar module with altitude emulator

- The sun's angle can be adjusted as a function of position (latitude), date and time
- The solar module's inclination can be adjusted
- 10-W polycrystalline solar module
- 500-W halogen lamp with dimmer
- Realistic emulation of the sun's path

Professional Photovoltaics

Modern Photovoltaic Systems Operating Parallel to the Grid

The design of photovoltaic systems operating in parallel with the electric power grid is realistic. In order to stabilise the electricity grid, the techniques of derating the power inverter and controllable local transformers are used. Knowledge and practical skills along with computer-based assessment of measured data are made possible by the advanced photovoltaics multimedia course along with SCADA Power Lab software.

Example experiment: "Setup for photovoltaic systems operating parallel to the grid" EPH 3

Training contents

Investigation of solar modules

- Recording of module response over days and years
- Testing optimum alignment of solar modules (to increase energy output)
- Recording characteristics of solar modules

Configuration of photovoltaic systems to operate in parallel with the power grid

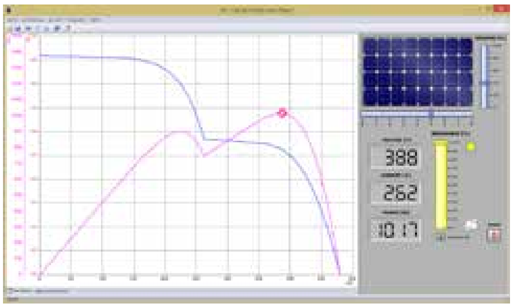
- Measurement of energy generated by photovoltaic systems
- Limiting the power of the photovoltaic inverter (derating)
- Determining the efficiency of the power grid inverter
- Response to control of the power grid inverter, MPP Tracking
- Recording output data using sun passage emulator
- Investigating the response of a photovoltaic system when there is a power outage on the grid
- Economic benefits of photovoltaic systems

Voltage control in a local power grid

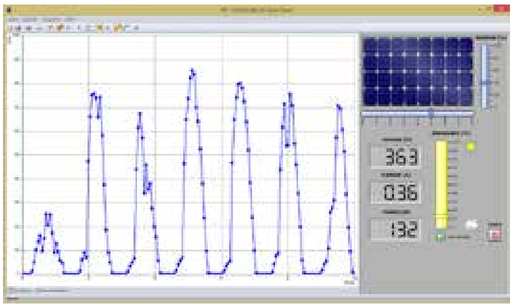
- Local-area network transformer
- Limiting the power of the photovoltaic inverter (derating)
- Automatic voltage control in a local power grid
- Operation and monitoring using SCADA

Professional Photovoltaics

Emulation of solar illumination via solar emulator



Photovoltaic emulator with shadow



Sunshine over the course of a week

Industrial inverter for photovoltaics with SCADA control

SCADA with derating of photovoltaic inverter

Your benefits

- Solar illumination emulator
- Latest technology featuring derating
- 3-phase feed into electricity grid
- Operation, observation and control via SCADA
- Use of industrial components
- Provision of reactive power
- Teaching via "Interactive Lab Assistant" course
- Flexible experimenting thanks to actual solar module or solar emulation

Investigation of battery storage units in conjunction with photovoltaic systems

An electrochemical energy storage device with a photovoltaic system is intended as a means of shifting or transferring power generation to periods of consumption or peak consumption periods to power generation periods. For this purpose, existent and available (solar) energy must be generated and subsequently stored so that it can be used in times of energy demand. The most important objectives of an electrochemical energy storage device are therefore:

- To increase own or private consumption
- To ensure dependable supply through backup power

Training contents

- Design and installation of the battery storage unit
- Putting the storage unit into operation
- Interaction between PV systems and storage units
- Boosting intrinsic consumption thanks to energy storage units

Wind Power Plants

Double-fed Induction Generator (DFIG)

This equipment set is designed for investigating modern wind power plants incorporating double-fed induction generators. The wind can be emulated realistically by means of a servo machine test stand and "WindSim" software. A PC can be connected for convenient operation and visualization during the experiments. The associated multimedia course titled "Interactive Lab Assistant" imparts theory besides supporting experiment procedures and evaluation of measurement data.

Sample experiment "Wind power plant" EWG 1

Training contents

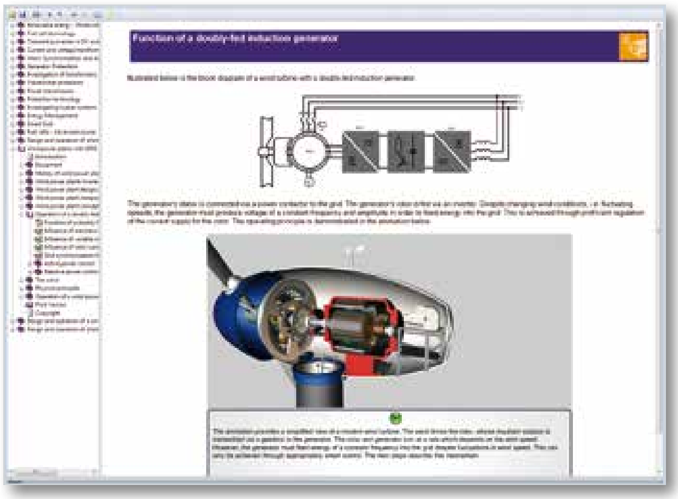
- Understanding the design and operation of modern wind power plants
- Exploring physical fundamentals from "wind to shaft"
- Learning about different wind power plant concepts
- Setting up and operating a double-fed asynchronous wind generator
- Operating the generator at varying wind force levels as well as adjustable output voltages and frequencies
- Determining optimum operating points under changing wind conditions
- Investigating responses to "fault-ride-through" grid mal-functions

Wind Power Plants

Fresh Wind in the Laboratory

Interactive Lab Assistant

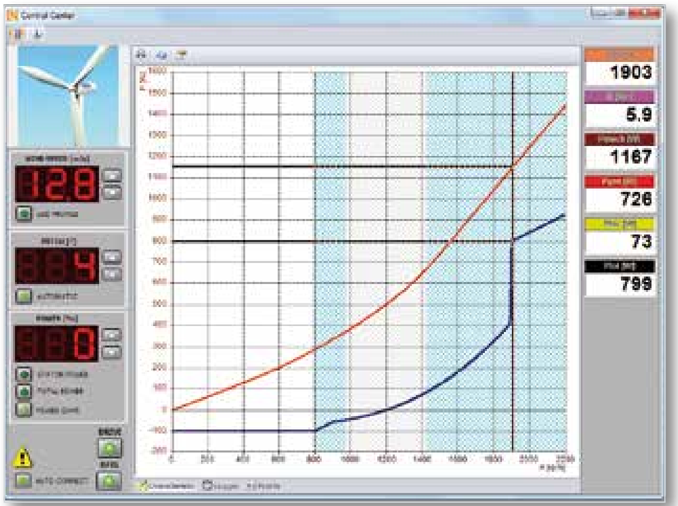
- Step-by-step instructions in multimedia format
- Explanation of physical principles using easily comprehensible animations
- Quiz and assessment tools for testing progress made during the course
- PC-supported evaluation of measurement data
- The following virtual instruments can be be started directly from the experiment instruction pages: Control Centre, DFIG Control, Synchroniser, Power Control, Status Control, Speed Control, FRT Monitor, Vector View, Oscilloscope and other measuring instruments

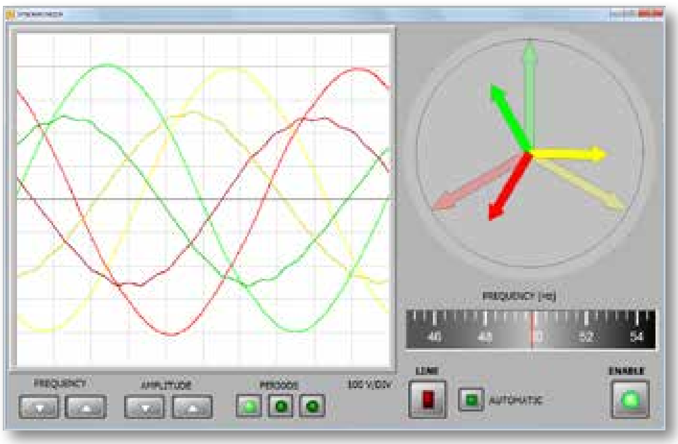


Wind emulator

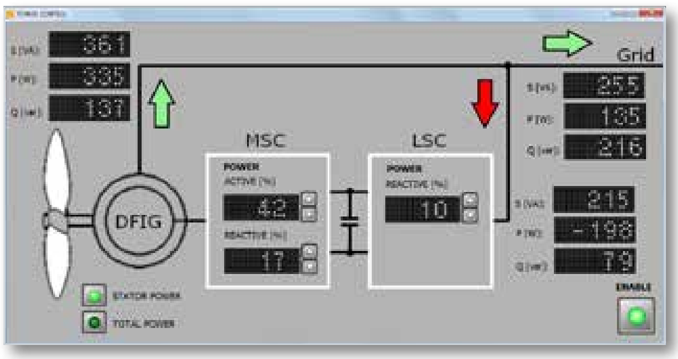
Wind and airfoil geometry serve to drive the generators at a real wind power plant. In the laboratory, this task is performed instead with the help of a servo machine test stand and WindSim software. This permits precise laboratory simulation of conditions prevailing at a real wind power plant.

- Realistic emulation of wind and airfoil geometry
- Speed and torque are matched automatically to wind strength and pitch
- Independently adjustable pitch and wind strength
- Wind profiles can be specified
- Mechanical and electrical variables can be recorded





Synchronisation of a wind power plant to the electricity grid



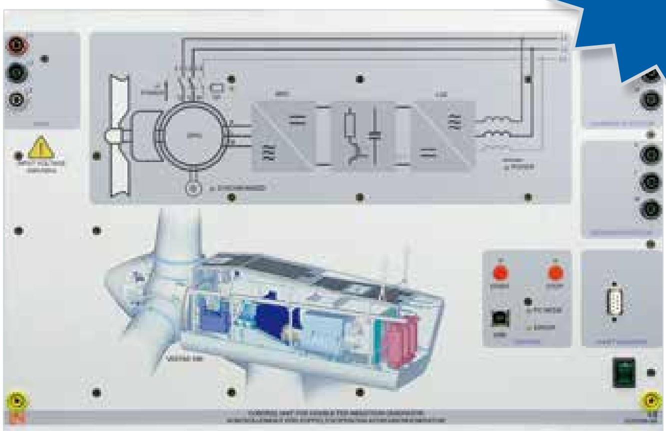
Power distribution and control of reactive power

Double-fed induction generator with control unit

- Control unit with two controlled inverters
- Generator control in sub-synchronous and super-synchronous modes
- Integrated power switch for connecting the generator to the network
- Automatic control of active and apparent power, frequency and voltage
- Manual and automatic synchronization
- Measurement and display of all system variables
- Experiments on fault-ride-through

"Double-fed induction generator"

"Fault-ride-through"



"Control unit for double-fed induction generator"

Your benefits

- Theoretical knowledge and practical know-how are conveyed using the Interactive Lab Assistant
- Wind power and mechanical design of wind power plants can be emulated accurately and in detail using the servo machine test stand
- The microcontroller-operated control unit for the double-fed induction generator permits user-friendly operation and visualisation during experimentation
- State-of-the-art technology incorporating "Fault-ride-through" (FRT)
- Integration into energy technology systems

Small Wind Power Plants

Decentralized Electricity Supply

Small wind power plants with outputs ranging up to 5 kW are deployed today for decentralized electricity supply. These plants generate direct voltages. The energy can be stored in batteries via charge controllers. Inverters produce alternating voltages to supply electrical consumers in the grid.
The effects of wind power and the mechanical design of wind power plants can be emulated down to the last detail using the servo machine test stand and the "WindSim software".

Sample experiment "Small wind power plant" EWG 2

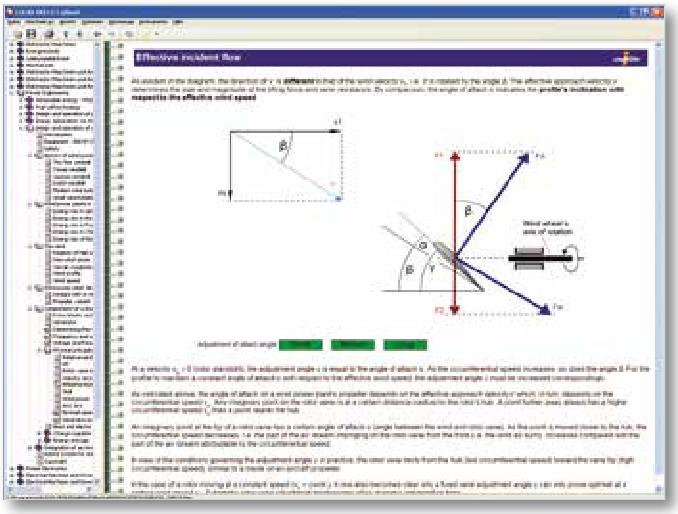
Training contents

- Understanding the design and operation of small, modern wind power plants
- Exploring physical fundamentals from "wind to shaft"
- Learning about different wind power plant concepts
- Setting up and operating a small wind power generator
- Operation at varying wind forces in storage mode
- Energy storage
- System optimization
- Setting up an off-grid system for generating 230-V alternating voltage
- Investigating hybrid systems for autonomous power supply using wind power and photovoltaic systems

Convincing Product Characteristics

Interactive Lab Assistant

- Step-by-step instructions in multimedia format
- Explanation of physical principles using easily comprehensible animations
- Quiz and assessment tools for testing progress made during the course
- PC-supported evaluation of measurement data
- Virtual measuring instruments can be started directly from the experiment manual



Synchronous generator

- Wind power and mechanical design of wind power plants can be emulated accurately and in detail using the servo machine test stand
- The laboratory generator's response is identical to that of one forming part of a real system
- The small wind power plant is suitable for outdoor operation

Your benefits

- Theoretical knowledge and practical know-how are conveyed using the Interactive Lab Assistant
- Wind power and mechanical design of wind power plants can be emulated accurately and in detail using the servo machine test stand
- The laboratory generator's response is identical to that of one forming part of a real system
- The realistic, small wind power plant is suitable for outdoor operation and includes an integrable mast set

Fuel Cell Technology

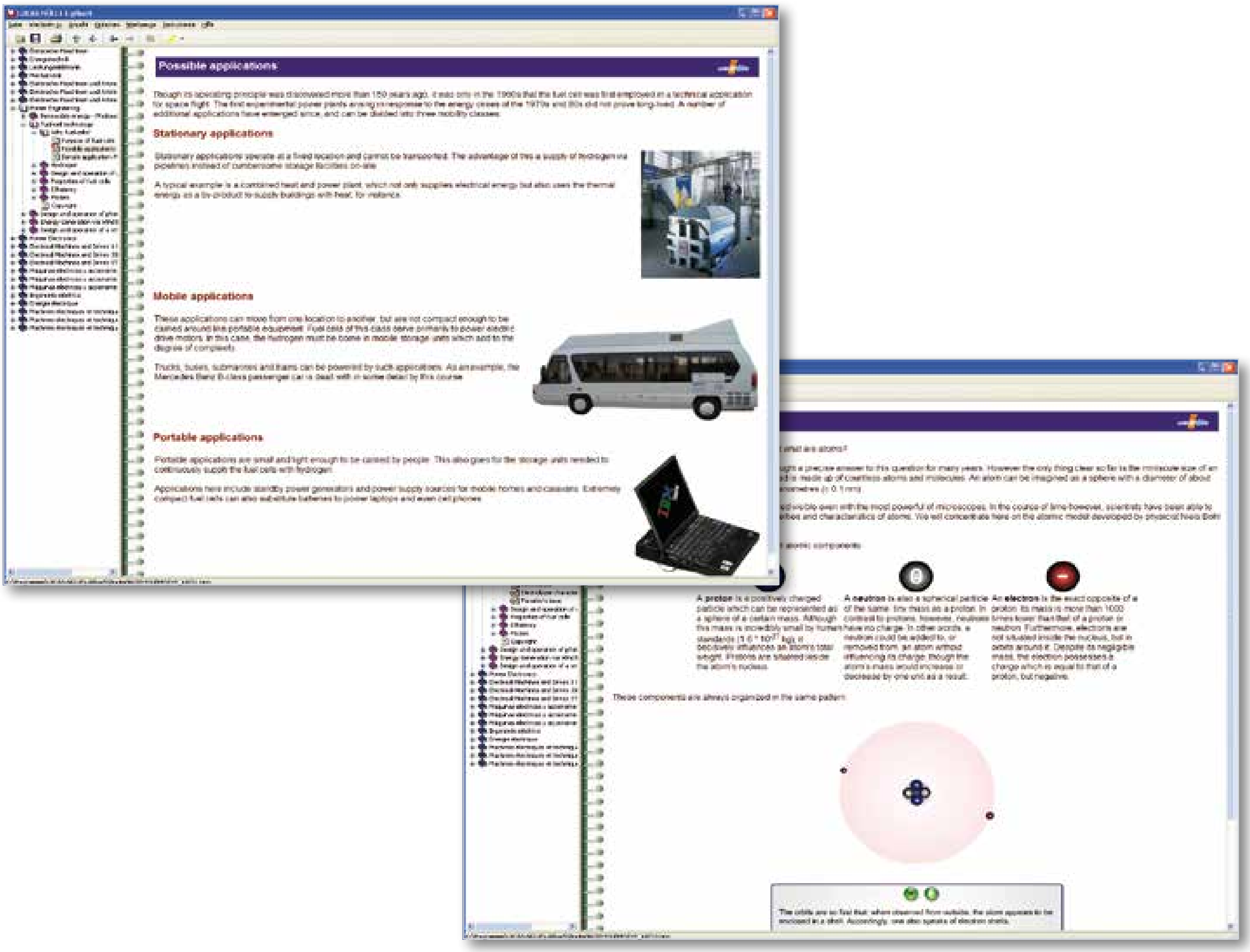
Design and Operation of Fuel Cells

Renewable energies are already considered a solution for dealing with expected energy shortages in the 21st century. The hydrogen-based fuel cell is part of this solution. As a complementary technology, it will be used in future energy systems to generate clean energy from renewable hydrogen.

Training contents

- Functions and operating principles of fuel cells
- Recording the characteristics of a fuel cell
- Understanding the electrochemical processes of electrolysis (Faraday's first and second laws)
- Determining a fuel cell's Faraday and energy efficiencies
- Series and parallel connections of fuel cells
- Power aspects of fuel cells
- Functions and operating principles of electrolysers
- Recording an electrolyser's UI-characteristic
- Determining an electrolyser's Faraday and energy efficiencies

Multimedia Course Consolidates the Experiment



Your benefits

- Theoretical knowledge and practical know-how are conveyed using the Interactive Lab Assistant
- Compact device with PEM double fuel cell and PEM electrolyser including a gas storage element
- Safe handling of hydrogen
- 2V/2.5A for supplying power to the integrated electrolyser
- Diverse loads (lamps, fans)
- Variable load for recording characteristics
- Course duration 4.5 h approx.

Advanced Fuel Cell Technology

Independent Electricity Supply with Fuel Cells

Generation of electrical energy using fuel cells continues to develop into a significant area with diverse potential applications in electrical and automotive engineering. Allowing safe handling of hydrogen and fuel cells, this experimentation system can be used for a number of interesting investigations and is suited for demonstrations as well as practical lab work. The "Interactive Lab Assistant" includes animated theory, experiment guidelines and result evaluation fields.

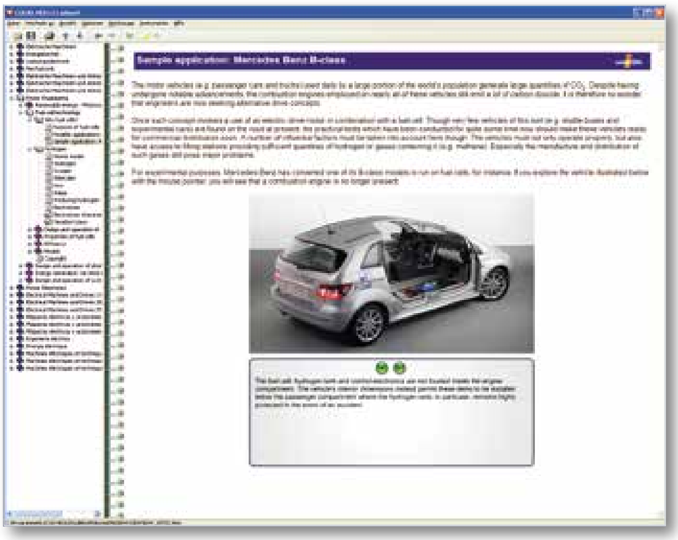
Sample experiment "50-VA fuel cell stack with loads" EHY 1

Training contents

- Design and operation of a fuel cell
- Design and operation of an electrolyser
- Design and operation of a metal hydride storage cell
- Fuel cell's thermodynamics
- Fuel cell's characteristic and power curve
- Efficiency
- Components needed for autonomous power supply
- Power electronics and voltage conversion

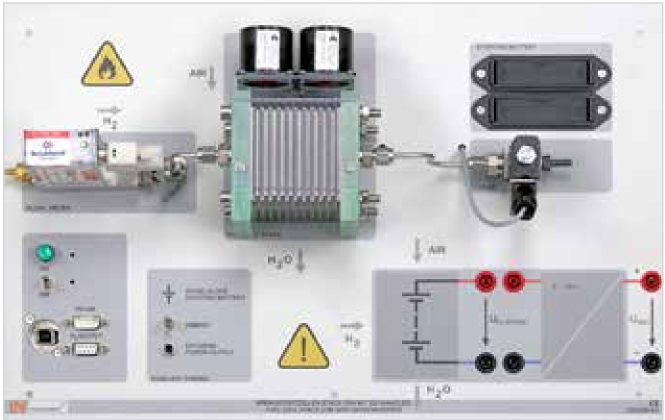
Interactive Lab Assistant

- Step-by-step instructions in multimedia format
- Explanation of physical principles using easily comprehensible animations
- Quiz and assessment tools for testing progress made during the course
- PC-supported evaluation of measurement data
- Virtual measuring instruments can be started directly from the experiment manual



Fuel cell stack

- 50-VA stack
- Hydrogen supply flow meter
- Variable-speed fan for fuel cell ventilation
- Measurement of all relevant variables



50-VA fuel cell stack

Your benefits

- Theoretical knowledge and practical know-how are conveyed using the "Interactive Lab Assistant"
- Simple introduction to the subject of fuel cells
- Safe experimentation with hydrogen
- 50-VA fuel cell stack
- Connection for pressurized hydrogen tank
- High-performance electrolyser
- Wide variety of loads
- Variable load for recording characteristics

Transformers

Transformers

Transforming and Protecting

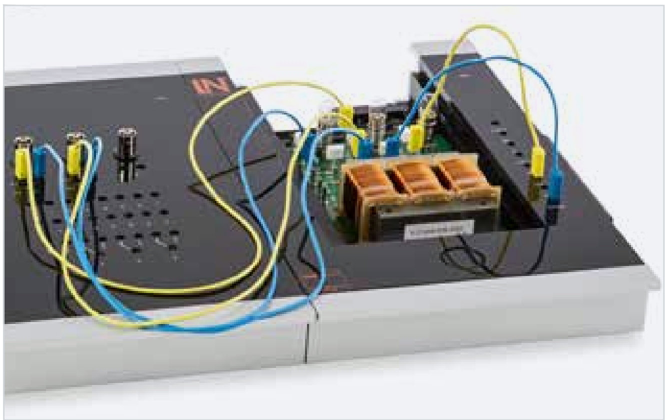
In power engineering, transformers are used to connect the various voltage echelons of the power grid to each other. In transformer stations, electricity from the regional distribution grid with a medium voltage level of 10 to 36 kV is transformed to supply power to low-voltage end customers in the local grid where 400 V or 230 V is used. The key component of a system for converting voltages is a transformer which also requires protective equipment. By carrying out hands-on measurements and fault simulations with the training system, it is possible to gain an understanding of these complex systems in the classroom.

Transformers
Transformers are electrical machines which serve to transform alternating or three-phase currents to higher or lower voltages. Three-phase transformers are of particular importance in the transmission of electrical power.
In power engineering, transformers are used to connect different voltage levels within the power grid to each other.

Source: SIEMENS

Transformer protection
Differential protection for transformers (starting from approx. 1 MVA), combined with time overcurrent protection, can be investigated using measurement techniques in normal operation, fault occurrences in various winding circuit configurations (star, delta), in various vector groups and as a function of star-point treatment (floating, direct or earthed using earth coils). In the case of differential currents, the tripping criteria is determined based on characteristic sensitivity.

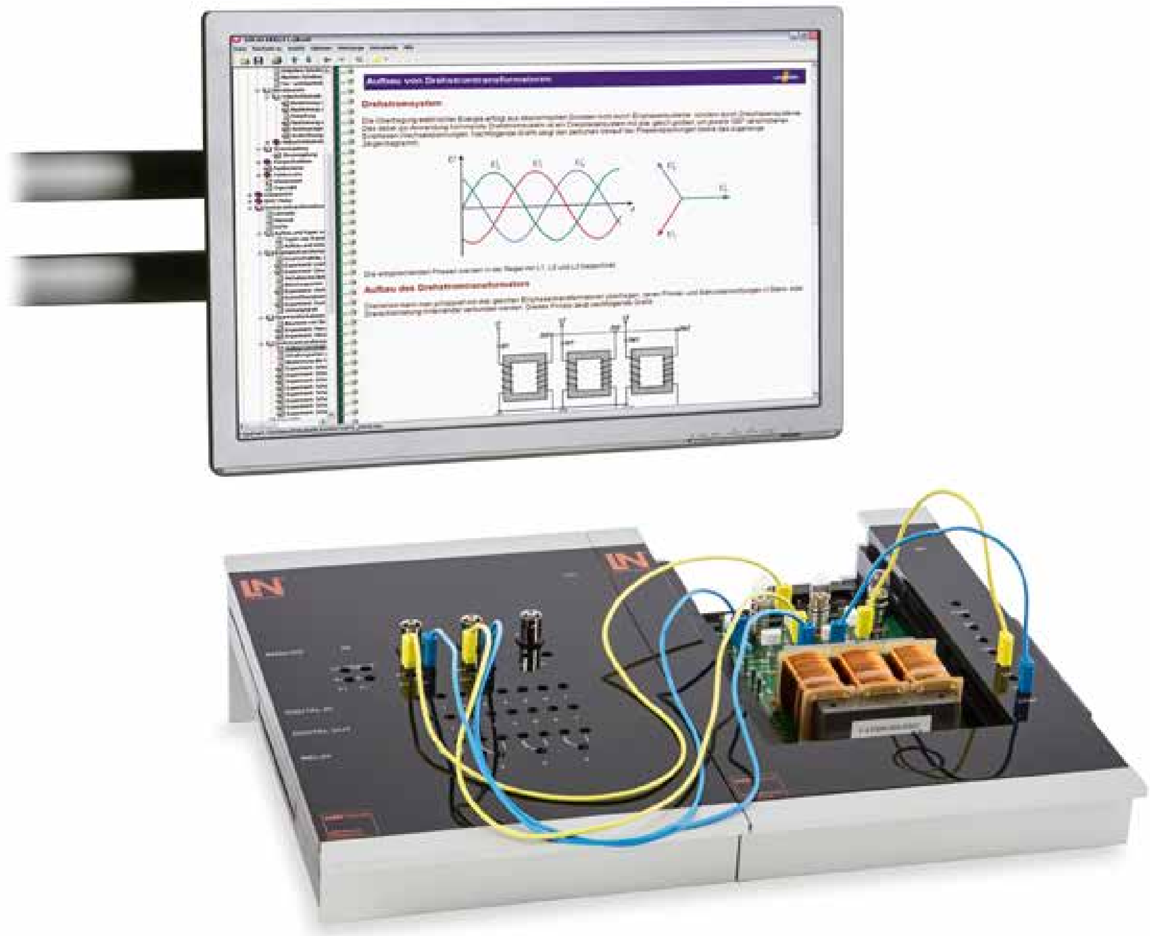
Training systems
Our training systems cover the following topic areas:
- UniTrain "three-phase transformer"
- "Transformer investigations" training panel system
- "Transformer protection" training panel system



Three-phase Transformers

Models, Connection Types, Load Response

Transformers are electrical machines which serve to transform alternating or three-phase currents to higher or lower voltage levels. Three-phase transformers are of special importance in the transmission of electrical power.



UNITRAIN SYSTEM

Training contents

- Learning about the transformer principle and equivalent circuit diagram
- Investigating the load response of single-phase transformers in single- and four-quadrant operation
- Recording current and voltage with and without loads
- Investigating the transformation ratio
- Investigating loads for different vector groups
- Investigating different vector groups in connection with unbalanced loads
- Determining the short-circuit voltage
- Course duration 3 h approx.

Investigating Transformers

Transformers

In power engineering, transformers are used to connect different voltage levels of the power grid to each other. In the experiments, the transformer's equivalent circuit diagram is examined and its parameters are determined by means of measurements.

Sample experiment "Investigating transformers" EUT

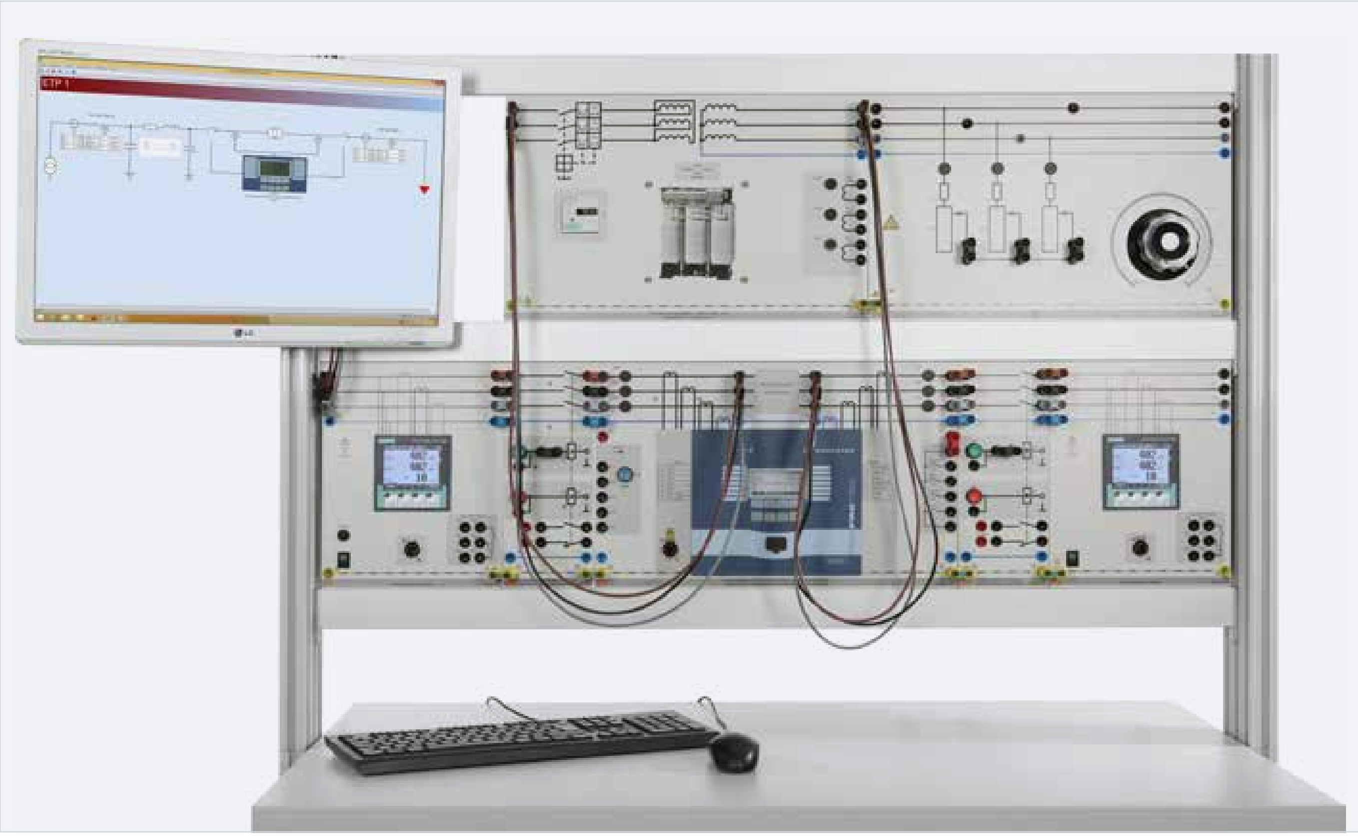
Training contents

- Multiphase transformer operating at no-load and short-circuit
- Multiphase transformer with ohmic, inductive and capacitive load
- Determining zero impedance
- Investigating the transformation ratio

Transformer Protection

Transformer Differential Protection

Differential protection for transformers (starting from approx. 1 MVA), combined with time overcurrent protection, can be investigated using measurement techniques in normal operation and fault occurrences in various winding circuit configurations (star, delta), and in various vector groups and as a function of star-point treatment (floating, direct or earthed using earth coils).



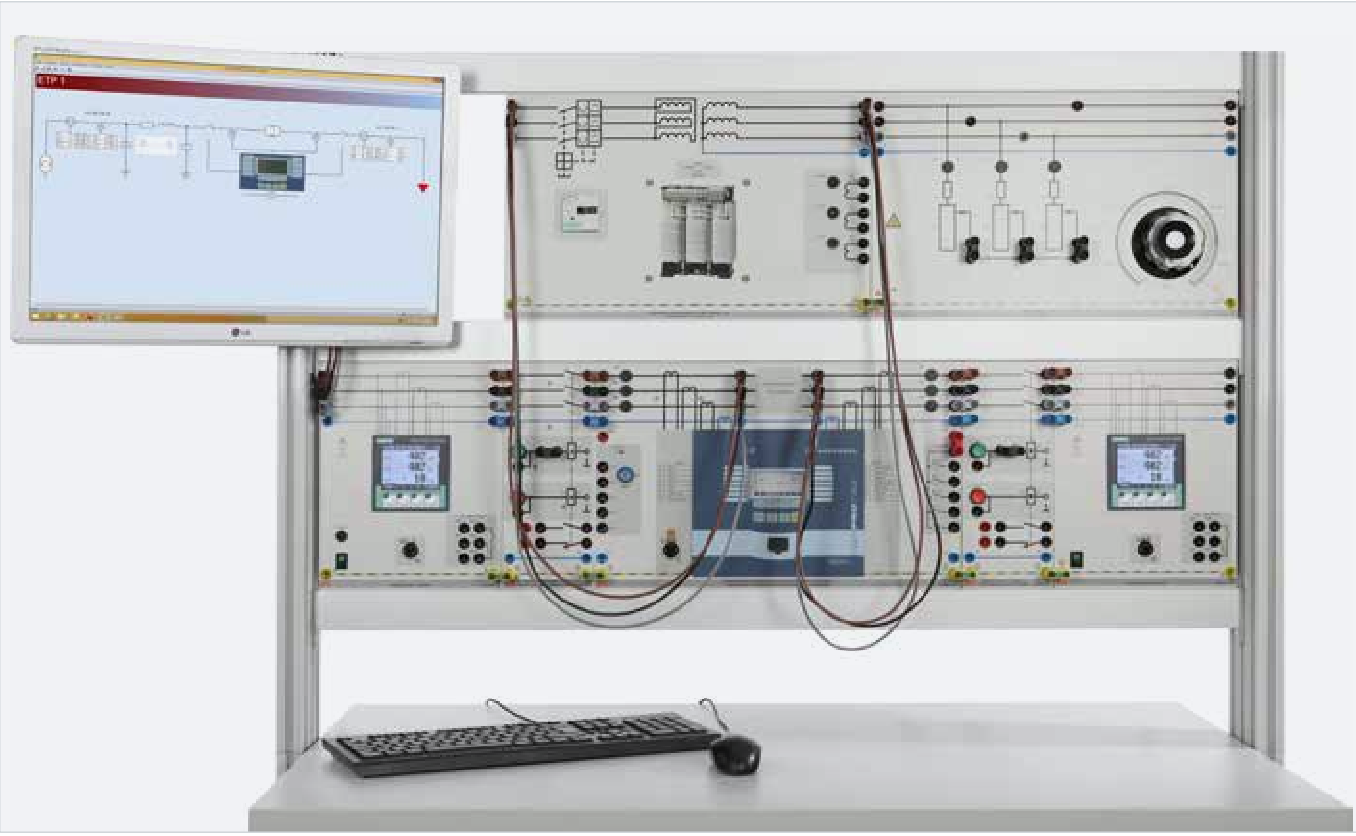
Sample experiment "Transformer differential protection" ETP 1

Training contents

- Detection and disconnection of transformer for internal faults
- Detection of peak inrush currents (RUSH) without disconnection
- Faulty tripping due to incorrectly dimensioned transformers
- Selection of tripping characteristics with differential currents taken into account

Time Overcurrent Protection

The time overcurrent protection supplements the safety protection measures contained in transformer differential protection. It protects the transformers against short circuits outside the protection range and against overloading.



Sample experiment "Time overcurrent protection" ETP 2

Training contents

- Setting the parameters of the time overcurrent relay while taking the current transformation into consideration
- Detection of operating values for symmetrical and asymmetrical faults
- False tripping of the protective device during transformer's switch-on response
- Transformer switch-on response in terms of protection

Power Transmission

Power Transmission

Transmission Lines and Measures to Protect Them

High-voltage networks are usually operated with voltages in the region of 110 kV to 380 kV, whereby urban areas and large-scale industrial facilities are supplied with 110 kV, and 380 kV is used for long-distance transmission lines. The line simulation system is designed for operation at model voltages between 110 V and 380 V. Various line lengths can be selected via corresponding overlay masks. Investigations can be made without a load, in a normal operating mode, in the presence of a short-circuit or earth fault or with asymmetric faults, including shorts to earth, with and without compensation. The system also permits assembly of complex networks by connecting the line simulation models in parallel or series. The voltage can be supplied via a fixed grid or synchronous generator.

High-voltage lines

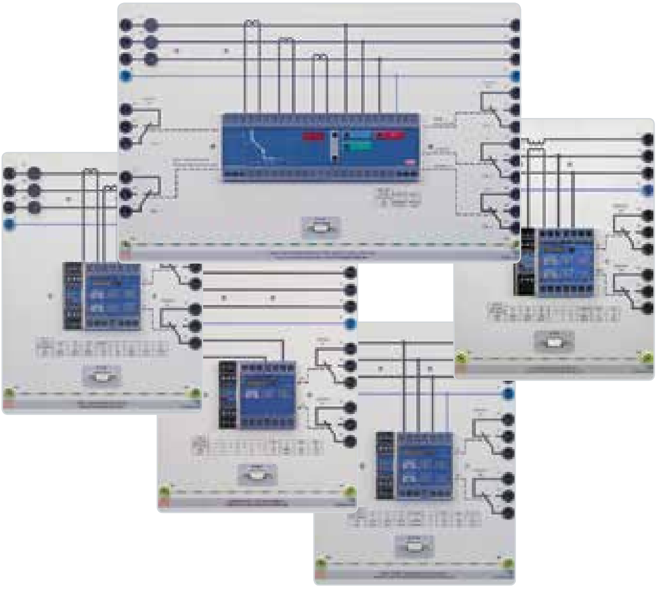
Your benefits:

- For your safety, the 380-kV transmission lines are investigated and connected at a low-voltage level without detracting from the characteristics of a real high-voltage line.
- Realistic simulation of a 380-kV transmission line with a length of 300 km or 150 km
- Innovative switchover between line lengths by means of overlay masks
- Earth-fault compensation by means of a Petersen coil
- Ability to simulate symmetric and asymmetric faults
- Series and shunt compensation

Innovative protection technology

In practice, medium-voltage and high-voltage networks are equipped with protective mechanisms connected via current and voltage transformers.

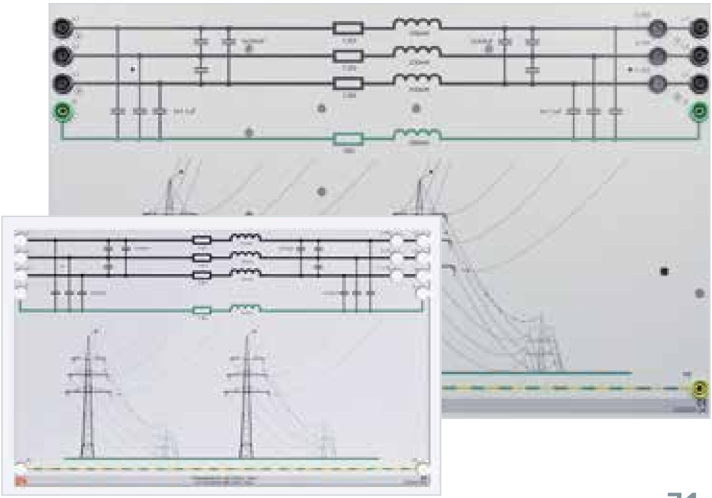
- Use of compact, original relays incorporating cutting-edge digital technology
- Use of industrial safety relays from prestigious international manufacturers
- Monitoring of protective features by means of SCADA (Supervisory Control and Data Acquisition)
- A relay test option permits the relays to be checked individually



Training systems

Our training systems cover the following topics:

- Experiment panel group - "Transmission lines"
- Experiment panel group - "Line protection"



Transmission Lines

Investigations on Three-phase Transmission Lines

For your safety, the 380-kV transmission lines are investigated and connected at a low-voltage level without detracting from the characteristics of a real high-voltage line. This realistic simulation of a 380-kV transmission line switches over automatically between line lengths of 300 km and 150 km once the overlay mask has been put into place.

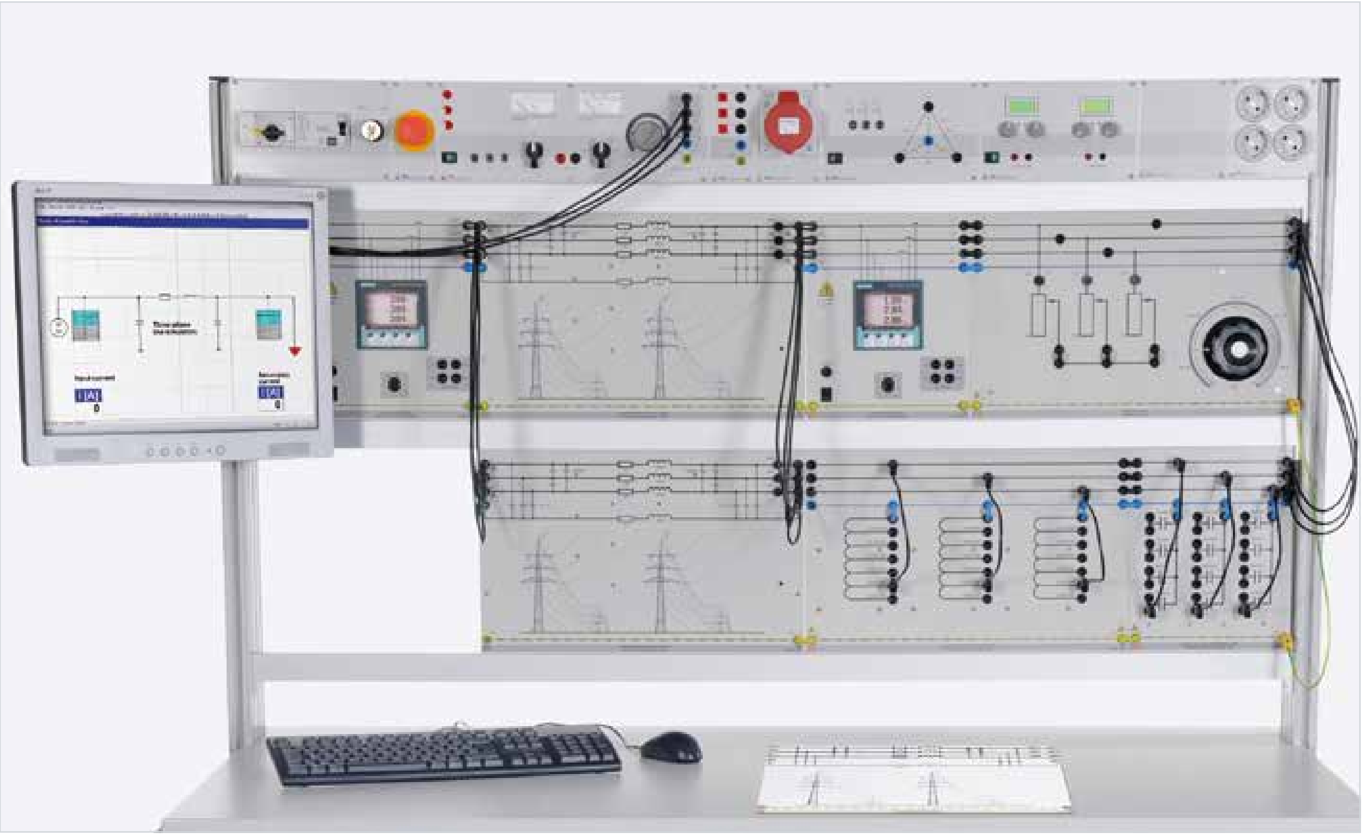
Sample experiment "Investigations on three-phase lines" EUL 1

Training contents

- Voltage increases on open-circuit lines
- Voltage drop as a function of line length
- Voltage drop as a function of load
- Capacitive and inductive power losses on a line as a function of U and I
- Phase shift on a line

Parallel and Series Connection of Transmission Lines

Joint use of several line simulation models connected in parallel or series permits complex networks to be assembled.



Sample experiment "Investigations on parallel lines" EUL 2

Training contents

- Distribution of power, voltage and current among parallel-connected lines of equal length
- Distribution of power, voltage and current among parallel-connected lines of unequal length
- Distribution of power, voltage and current among series-connected lines of equal length
- Distribution of power, voltage and current among series-connected lines of unequal length
- Load distribution, power flow
- Quantitative and qualitative evaluations of operational relationships

Transmission Lines

Transmission Line with Earth-fault Compensation

Earth-fault compensation in electric power supply networks is designed to offset earth leakages occurring in outer conductors. Restricted to three-phase systems, earth-fault compensation makes use of a special Petersen coil named after its inventor and which is also known as an earth-fault quenching coil. This coil compensates the electric current at the earth-fault point, thereby preventing consequential malfunctions in the electrical system.

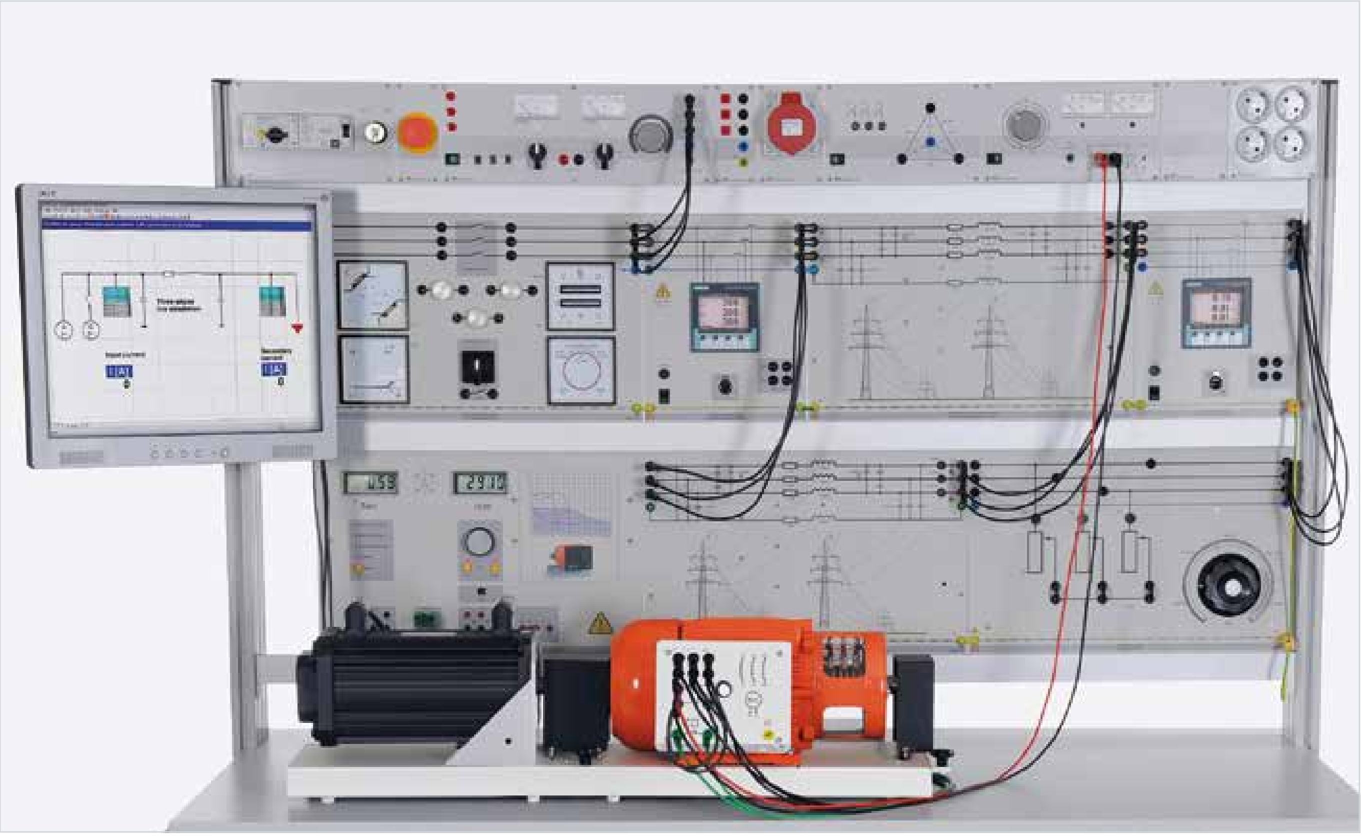
Sample experiment "Investigations on lines with earth-fault compensation" EUL 3

Training contents

- Earth fault on a line with an isolated star point
- Response to earth faults
- Earth-fault compensation
- Tuning to resonant frequency

Transmission Systems with a Synchronous Generator

The objective here is to measure characteristic power transmission parameters on simulated, three-phase, parallel-connected lines fed via a fixed network or a generator, and perform quantitative as well as qualitative assessments of operational relationships.



Sample experiment "Investigations on transmission systems with a synchronous generator" EUL 4

Training contents

- Power and current distribution in a line network fed by a generator
- Parallel operation of a generator and line via the network
- Control of active power feed
- Control of reactive power feed

Transmission Lines

Three-phase Cables

A high-tension cable is one that is designed for use with high voltages. Cables of this type are used, among other things, for transmitting large quantities of power in grids supplying electrical energy as an alternative to overhead lines. High-tension cables can be categorised into the most important design types: earth cables, oil-filled cables, gas-pressure cables and plastic cables. The objective of the experiments is to investigate the response of high-tension cables to a variety of operating conditions.

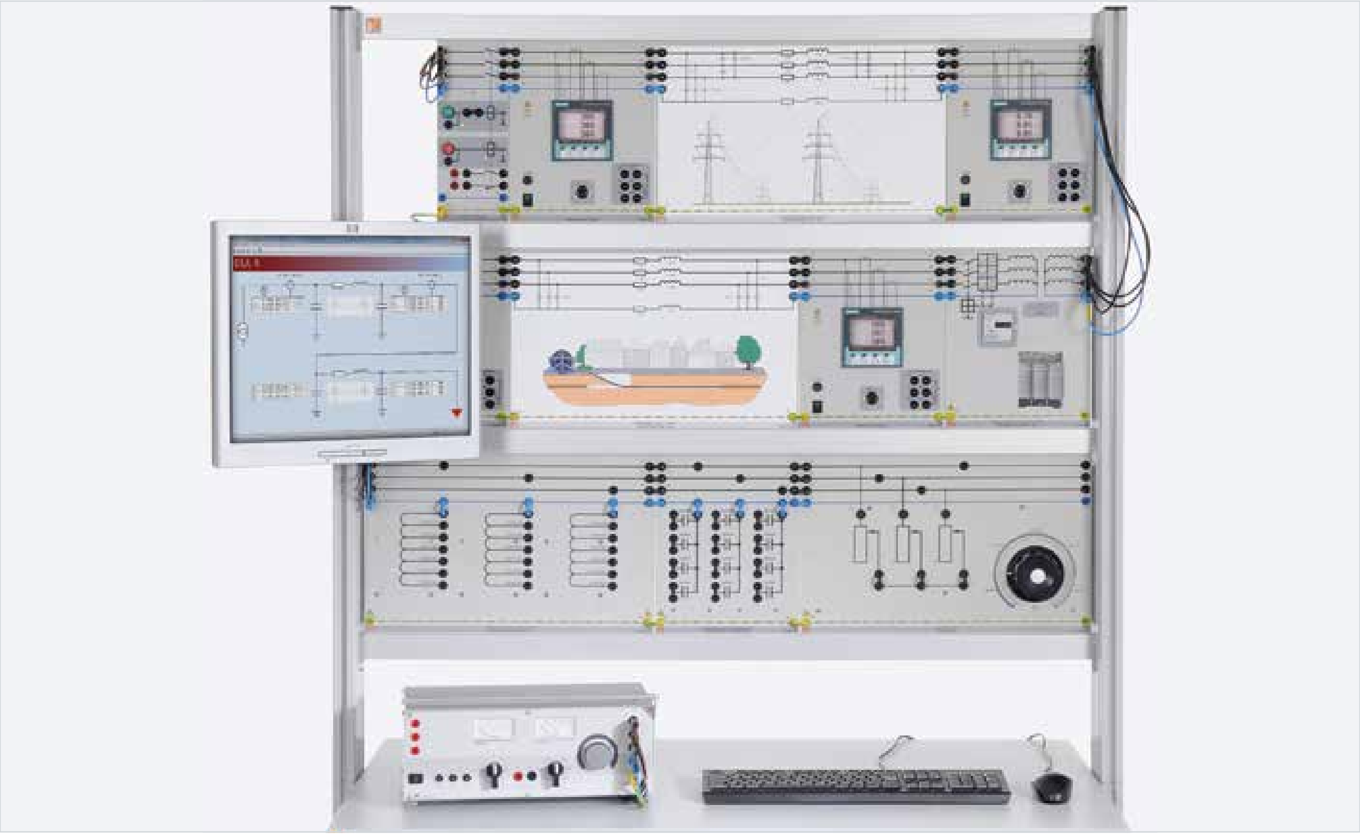
Sample experiment „Investigations on three-phase cables" EUL 5

Training contents

- Ferranti effect, loading capacity, critical length
- Resistive, inductive and combined resistive and inductive loading
- Compensation for a resistive-inductive load
- Determining zero impedance
- Symmetrical and asymmetrical short circuits
- Star (Y) point treatment and faults to ground

Interconnected Grid Network with Cables and Overhead Lines

In electrical power supply grids, both cables and overhead transmission lines are used to transport energy. This experiment involves investigating the properties of a power transmission line segment composed of both ground cables and overhead power lines.



Sample experiment „Investigations on interconnected network grids with cables and overhead lines“ EUL 6

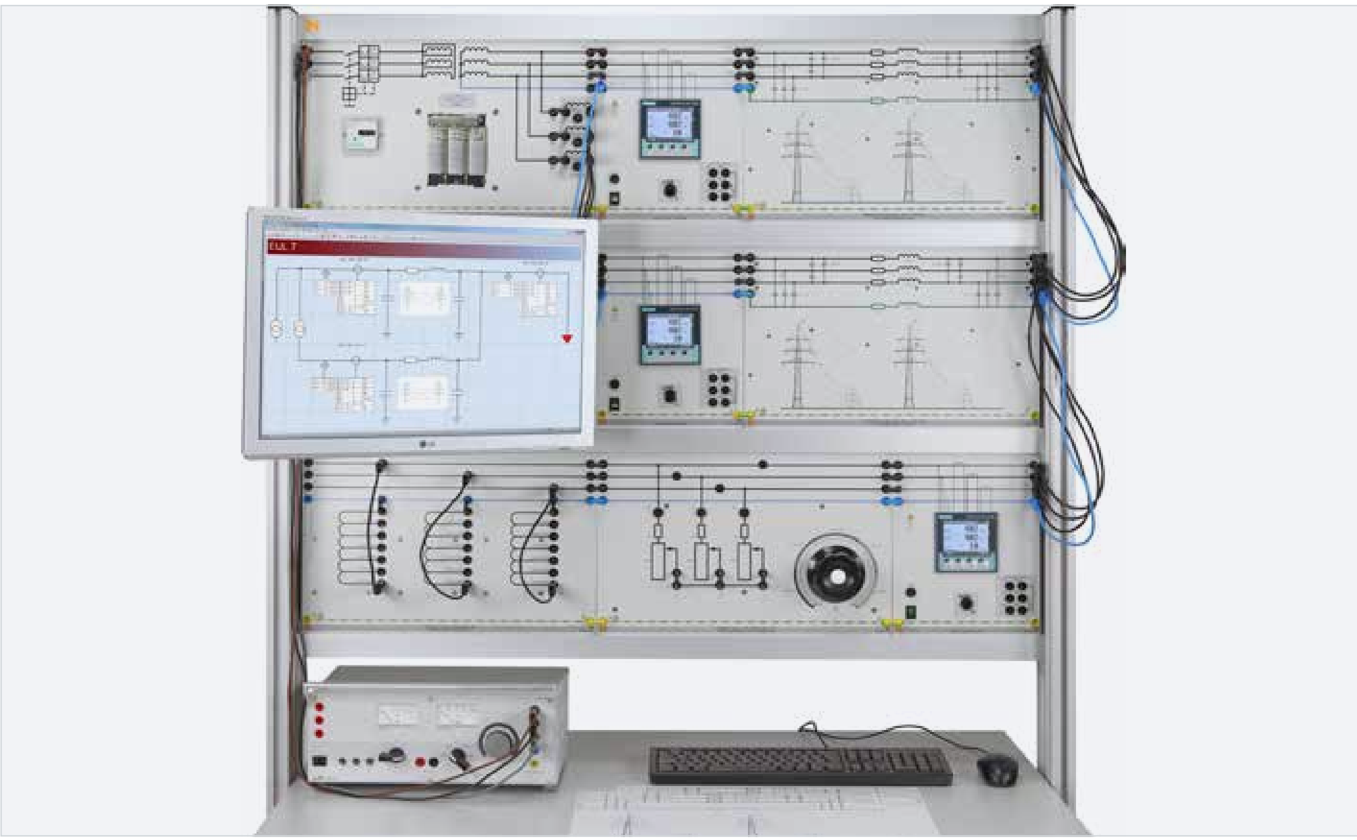
Training contents

- Differences between cables and overhead lines
- Investigation of lines from end to end:
  - Overhead line-transformer-cables
  - Cable-transformer-overhead line
- Observation of power losses from individual components
- Comparison between theory and practice
- Parameters for a voltage transformer station

Power Transmission Lines

Controlling power flow in meshed networks

The power flow between two node points of a network is determined by the difference between their two voltages. In this course it is demonstrated that the differential between the voltage magnitudes primarily affects the reactive power flow, while the differential between the voltage phase angles determines the active power flow. As a rule variable-voltage transformers exploit these conditions by being in a position to not only adjust the magnitude of the transformation ratio but also the angle between the voltages on both sides. In addition to providing improved voltage stability, these kinds of transformers also feature the capability to control active and reactive power flows in power networks.



Experiment example "Power flow control in meshed operated networks EUL7 "

Training content

- Variable-voltage transformers
- Differences between regulated and unregulated transformers
- Transformer with in-phase voltage control
- Transformer with quadrature voltage control
- Transformer with phase-angle voltage control
- Monitoring and influencing power flows in the grid
- Comparing theory with practice

Load-dependent voltage regulation of a power transmission line

Transformers are designed to connect up voltages of varying levels. They normally do not have a fixed transformation ratio, but instead can adapt to the respective load situation by tapping different winding ratios. This is how it is possible to ensure that voltage fluctuations arising within the supply grid can be diminished accordingly and that consumers can be supplied for the most part with stable voltages. Here we will examine how an auto-connected regulating three-phase variable transformer responds when operated in conjunction with a transmission line model and a connected load.

Experiment example "Load-dependent voltage control of a power line EUL8"

Training content

- Voltage range of a three-phase variable transformer in auto-connected regulating configuration
- No-load and short-circuit response of the autotransformer
- Combination of three-phase variable transformer and power transmission line model including connected load
- Automatic voltage adjustment for random load currents
- Step-up transformer
- Step-down transformer

High-voltage DC power transmission

Sustainable power transmission for the efficient and reliable energy grids of the future

High-voltage DC power transmission is a method of transmitting electrical energy by means of high DC voltage. High-voltage technology (HVDC) is designed to exploit direct current as a means to transmit power over long distances since above certain longer distances the high-voltage DC transmission features lower overall power losses than is the case for conventional transmission using three-phase AC power, despite the additional converter losses. High-voltage DC transmission is frequently used for power transmission over comparably short distances if the power transmission cable has been designed with a very high degree of capacitance per unit length. This is typically the case with submarine cables but also underground terrestrial cables.

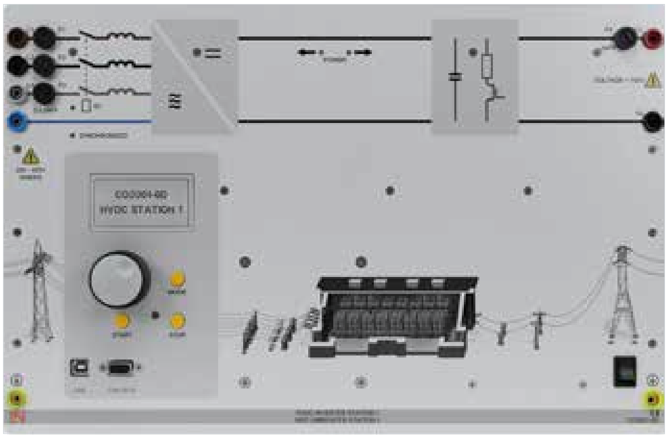
Experiment example "High voltage DC transmission" EDC1

Training content

- Control of intermediate circuit (link) voltage
- Provision of reactive power but with no effect on the flow of active power (STATCOM)
- Manual and automatic synchronisation with the electric power grid
- Control of HVDC reactive power with modification to the flow power
- Individual control of reactive power for both converter stations
- Observation of losses for various lengths of HVDC lines
- Provision of a power network with passive consumers by means of HVDC (black start)
- Coupling of wind turbines
- Investigation of fault ride-through (FRT) behaviour in HVDC systems

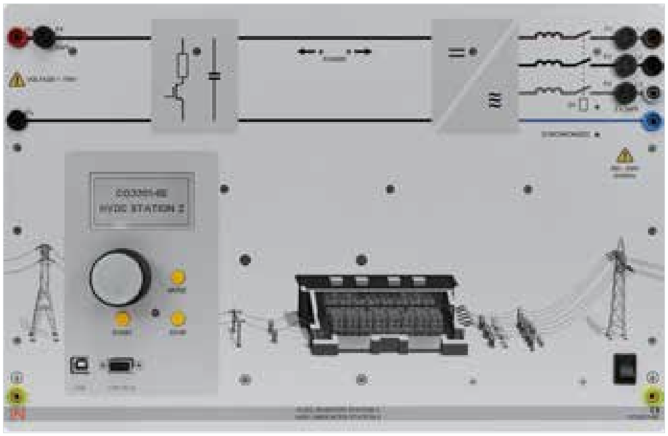
Converter station 1

- STATCOM operation
- Coupling between grids with different frequencies
- Self-sufficient automatic control of reactive and active power, frequency, voltage
- Measurement and display of all system variables
- Transmission of up to 1000 W active power



Converter station 2

- Active power control in both directions
- Connection of synchronous generators, wind power plants and loads
- STATCOM operation
- Coupling between mains with different frequencies
- Self-suffi cient automatic control of reactive and active power, frequency, voltage
- Measurement and display of all system variables
- Manual and automatic synchronisation with active grids
- Transmission of up to 1000 W active power



Your benefits

- Imparting knowledge and know-how using a multimedia-based course "Interactive Lab Assistant"
- PC-based evaluation of measurement data
- New technologies of voltage source converter (VSC)
- Integration into the power engineering systems
- State-of-the-art technology including "Fault-ride-through"
- The microcontroller-operated control unit of the converter station permits comfortable operating control and visualisation during the experiments

High-voltage DC power transmission

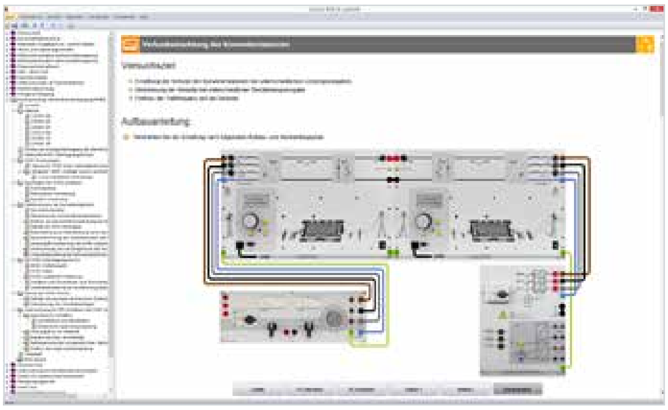
Interactive Training Environment

"Interactive Lab Assistant"

- Multimedia-based step-by-step instruction guide
- Tests of learning progress using question pool with assessment tool

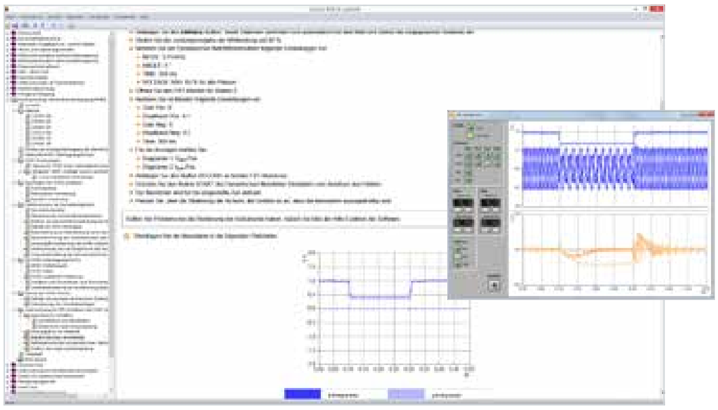
Theory

- Explanation of physical principles by means of easily understandable animations



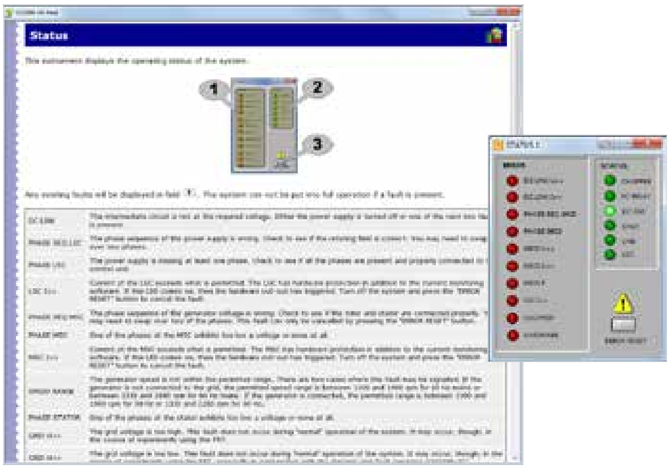
Experiments

- Interactive illustration of experiment set-ups



Measurements and results

- PC-supported evaluation of measurements
- Virtual instruments can be started directly from the experiment instructions
- Measurement results can be copied into the course pages via "drag and drop"



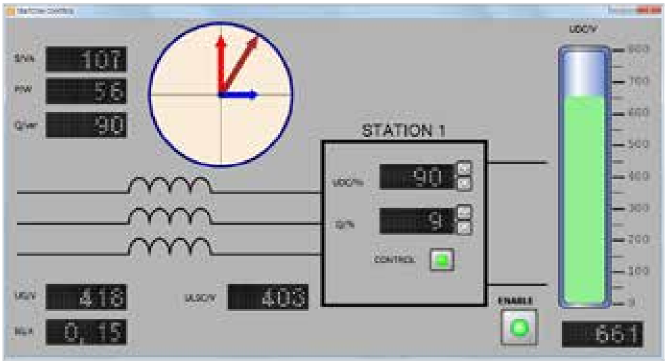
Status display

- Status and fault displays for converter stations
- Extensive help function

Various Operating Modes

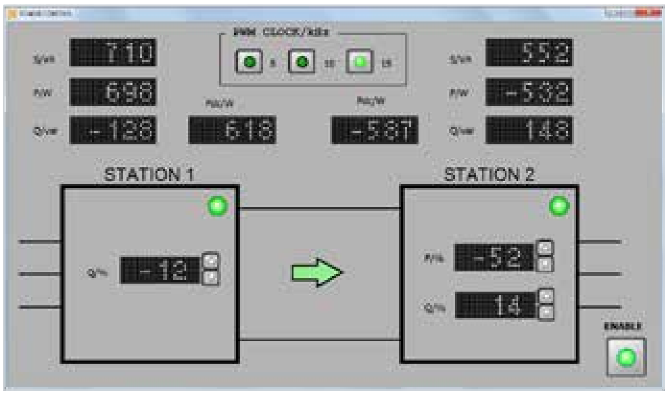
"STATCOM" instrument

- Works even when the transmission line is not operating
- Control of DC link circuit
- Control of reactive power



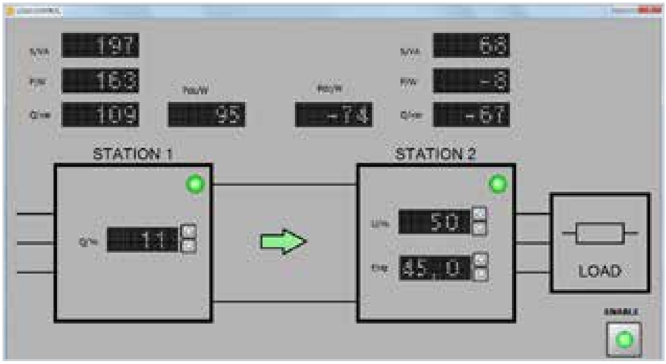
"Power control" instrument

- Control of active power in both direction
- Control of active and reactive power in all 4 quadrants
- Automatic synchronisation



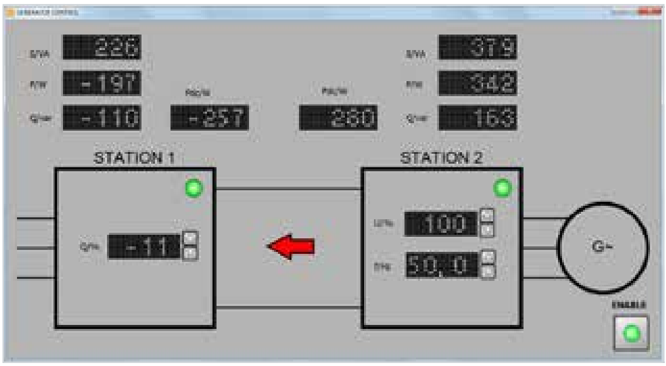
"Load control" instrument

- Supplying a network with passive loads only
- Black starts
- Pre-setting of voltage and frequency on load side
- STATCOM on grid side



"Generator control" instrument

- Coupling of wind power plants without additional generator
- Black starts
- Pre-setting of voltage and frequency on generator side
- STATCOM on grid side

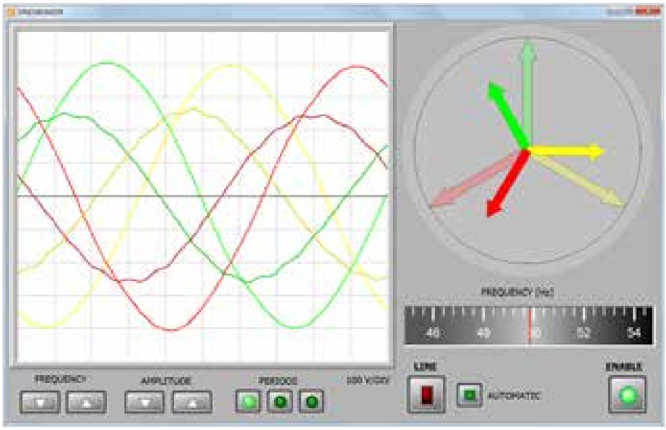


High-voltage DC power transmission

Virtual Instruments

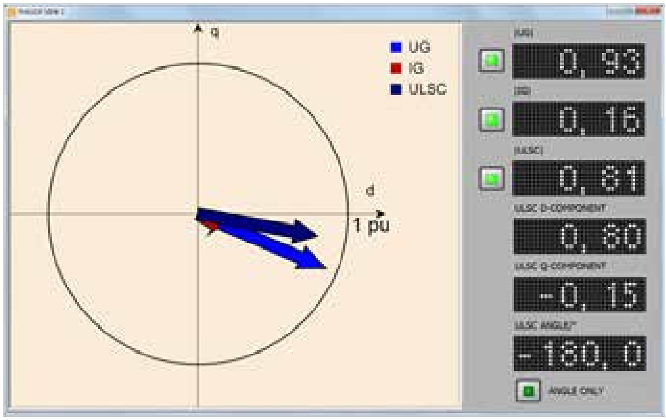
"Synchroniser" instrument

- Automatic and manual synchronisation of converter station with grid
- Three-phase display of grid and converter voltages
- Control of converter output voltage and frequency



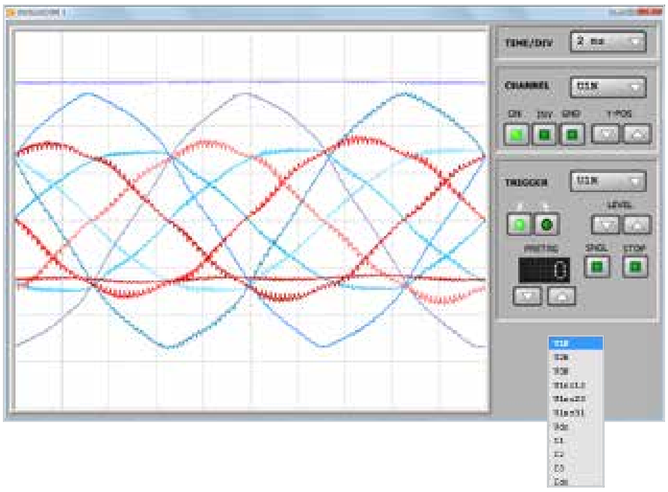
"Phase diagram" instrument

- Display of converter station currents and voltages in a phase diagram
- Display of symmetric components
- Separate instruments for every converter station



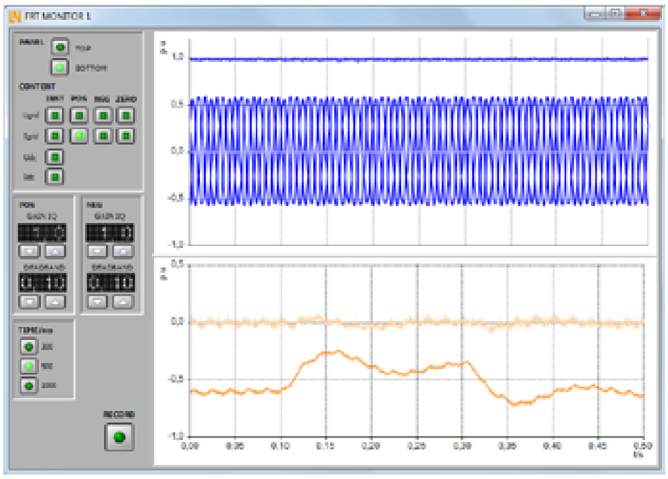
"Oscilloscopes" instrument

- Display of all signals from converter stations
  - Grid voltages
  - Grid currents
  - DC voltage
  - DC current



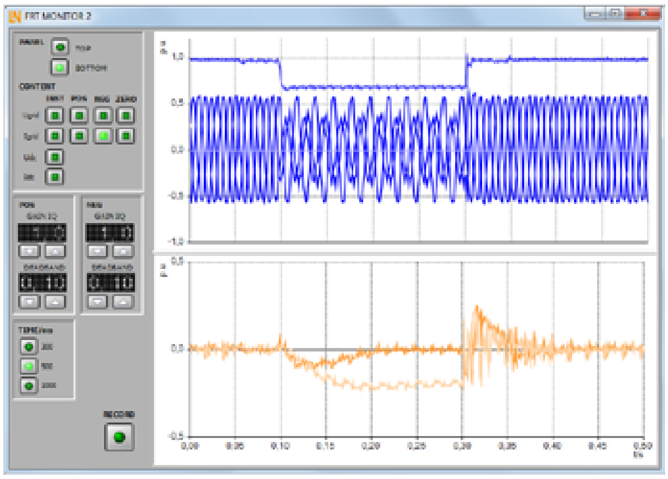
"FRT Monitor" instrument for Station 1

- Setting of "grid codes"
- Display of symmetric components
- Display of instantaneous values
- Simultaneous measurements from both stations



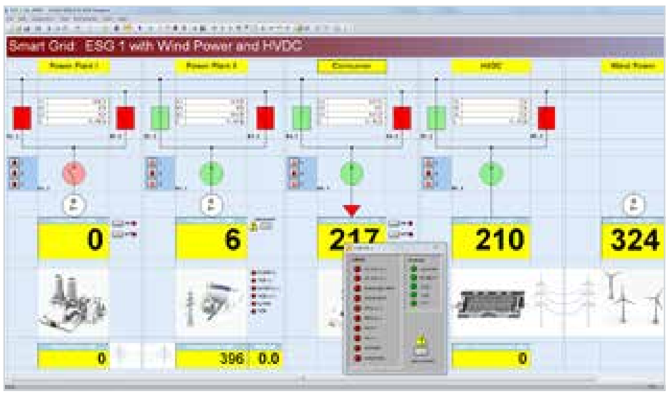
"FRT Monitor" instrument for Station 2

- Setting of "grid codes"
- Display of symmetric components
- Display of instantaneous values
- Simultaneous measurements from both stations
- Investigations with wind power plant connected



SCADA control

- Monitoring of converter stations in a smart grid
- Control of converter stations via SCADA
- Supplying a smart grid with active and reactive power



Line Protection

Overcurrent Time Protection for Lines

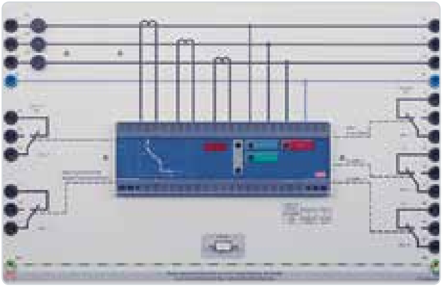
Items covered in this experiment series include overcurrent time relays whose time characteristic is independent of the current and which are usually employed on single-wire (branch) lines.

Sample experiment "Overcurrent time protection for lines" ELP 1

Training contents

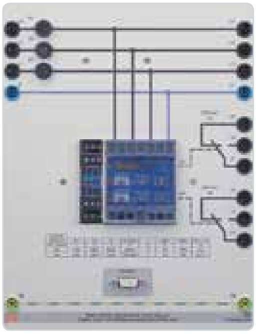
- Designing and parameterising overcurrent time protection
- Determining the reset ratio in the case of single-, double- and triple-pole short circuit
- Determining a relay's shortest release time
- Checking a circuit breaker's release behaviour in the event of a failure

Auxiliary Line Protection Equipment



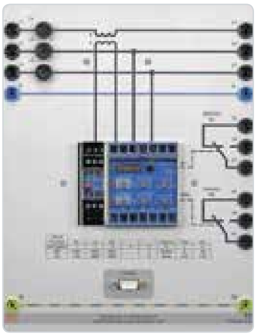
ELP 2 Directional overcurrent time protection

Training contents
- Designing and parametrizing overcurrent time protection
- Determining the reset ratio in the case of single-, double- and triple-pole short circuit
- Forward and reverse protection



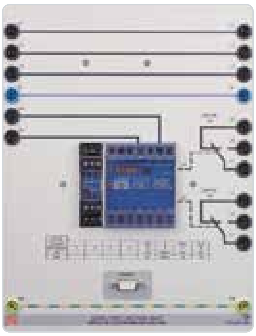
ELP 3 Overvoltage and undervoltage protection

Training contents
- Determining rise and fall times
- Determining the reset ratio
- Determining the inherent time
- Setting and testing various characteristics



ELP 4 Directional power protection

Training contents
- Determining rise and fall times
- Implementing protection against reverse loads
- Interaction with overcurrent time relays



ELP 5 Earth-fault detection

Training contents
- Measuring voltages in a sound, three-phase network
- Measuring voltages in a three-phase network experiencing earth faults
- Determining rise and fall times
- Determining the inherent time
- Relay responses to momentary and permanent earth faults

Line Protection

Protection of Parallel-connected Lines

Used mainly for protecting parallel-connected lines, the directional overcurrent protection relay is tested through fault simulation here, besides being analyzed and investigated experimentally in terms of selectivity and speed.
Networked via a bus system, the protective relays can be operated and evaluated by means of the SCADA Power-LAB software.

Sample experiment "Protection of parallel lines" ELP 6

Training contents

- Protecting parallel-connected lines with different overcurrent time relays
- Parallel operation in the fault-free state
- Determining minimum response values for non-directional overcurrent time relays
- Determining directions of protection for directional overcurrent time relays
- Determining minimum response values for directional overcurrent time relays
- Time grading for overcurrent time relays
- Checking selectivity through combined overcurrent and directional measurements
- Networking protective measures

High-speed Distance Protection

Various faults can be analyzed in the case of the high-speed distance protection relay employed for more complex networks. This type of protection permits faults to be isolated in dependence of their distance. Besides preparation of a tripping schedule, selectivity can be set and tested in a practical manner.

Sample experiment "High-speed distance protection" ELP 7

Training contents

- Preparation of a grading schedule
- Relay parameterisation
- Operating a distance protection relay with current and voltage transformers
- Tests of triggering characteristics in the event of various faults inside and outside the line's protective domain
- Tests of triggering characteristics in the event of various faults inside and outside the protective domain:
  - Distance protection
  - Overcurrent time protection
  - Voltage protection
  - Frequency protection

Electric Power Distribution

Electric Power Distribution

Busbars at high-voltage switching stations

Electrical power at large switching stations is distributed almost exclusively using double busbar systems. These stations incorporate switching matrices for connecting the two busbars, the incoming and outgoing feeder cubicles as well as the measurement fields. The incoming and outgoing feeder cubicles as well as the switching matrices are furnished with circuit breakers and one disconnector for each busbar terminal. For safety reasons, a particular switching logic must be strictly adhered to here. The double busbar model incorporates all functions of practical relevance. Integrated instruments for measuring currents and voltages permit direct analyses of switching operations.

Double busbar systems

The compact modules named "Incoming and outgoing feeder cubicles" and "Switching matrix" offer the following advantages:

- Flexible arrangement of the various fields
- Operation and monitoring from a PC
- Networking capability thanks to an RS-485 interface
- Manual operation
- Integrated microcontroller for preventing incorrect operation
- Registration of all characteristic parameters such as current, voltage and switching states

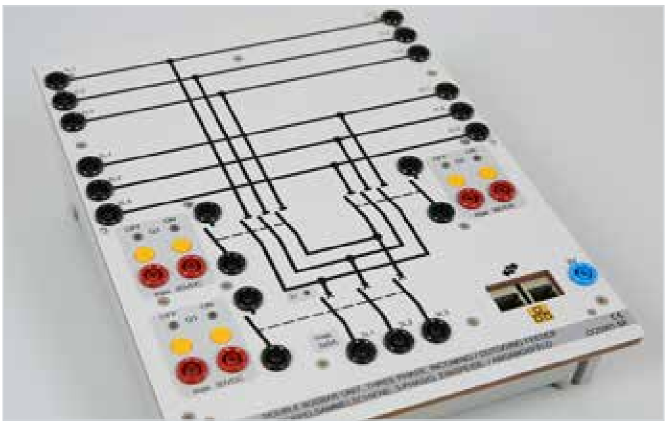
SCADA

Devices are monitored and controlled by means of the SCADA (Supervisory Control and Data Acquisition) system. All devices belonging to Lucas-Nülle's energy technology programme can be arranged as desktop icons and linked together. Measurement values and operating states are indicated. Important parameters and signals can be controlled via the software. Measurement values and operating states can be recorded, displayed as functions of time, and analyzed. Automatic switchover between busbars can be performed via the PC.

Training systems

Our training systems cover the following topics:

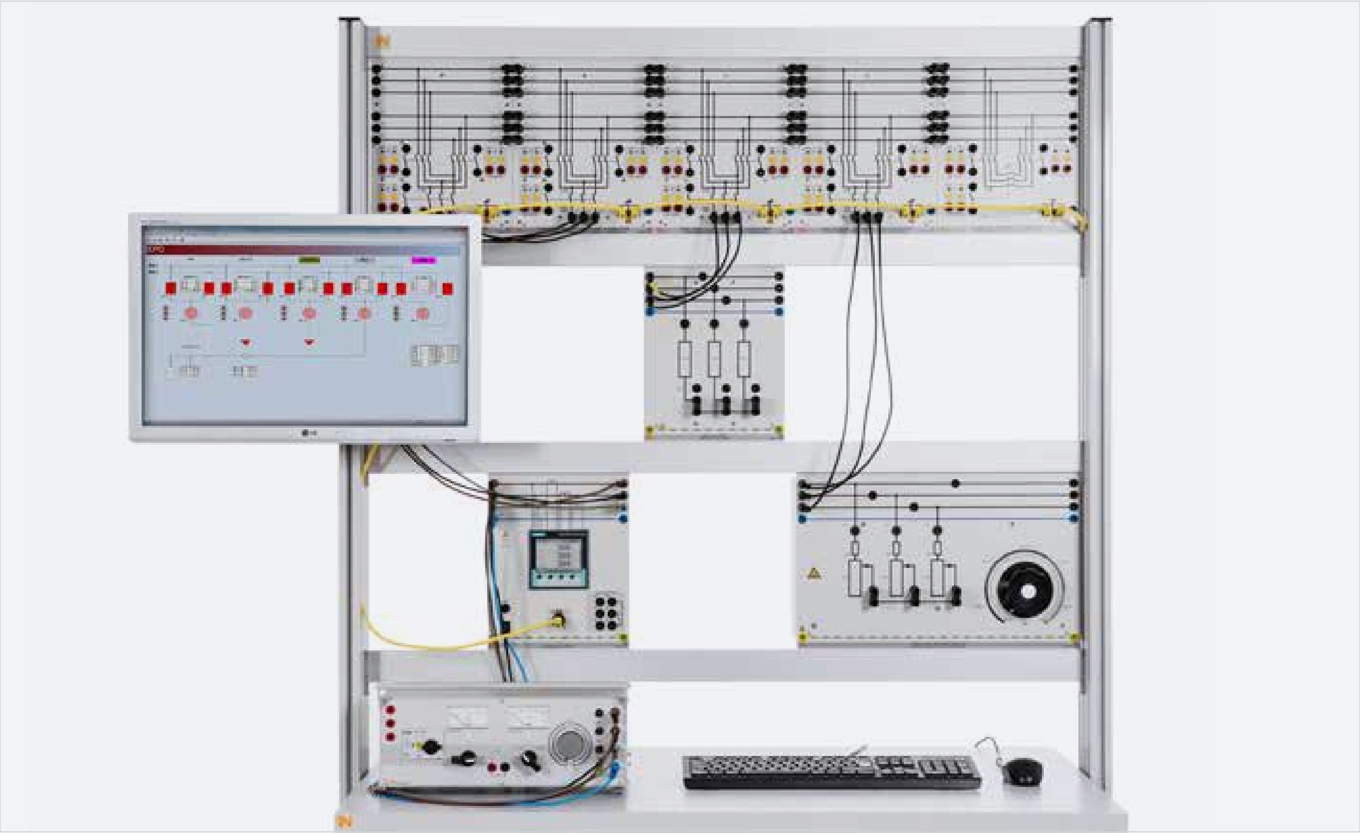
- Experiment panel group - "Three-phase double busbar system"
- Experiment panel group - "Overcurrent protection for busbars"



Three-phase Double Busbar System

Central Distribution and Control

Busbars serve as central distributors of electrical energy, all incoming and outgoing lines being connected to the busbars. Busbars comprise incoming and outgoing feeder cubicles, switching matrices and converter panels.
As part of Lucas-Nülle's equipment sets, these functions are grouped into switching fields containing circuit breakers, disconnectors and data loggers.



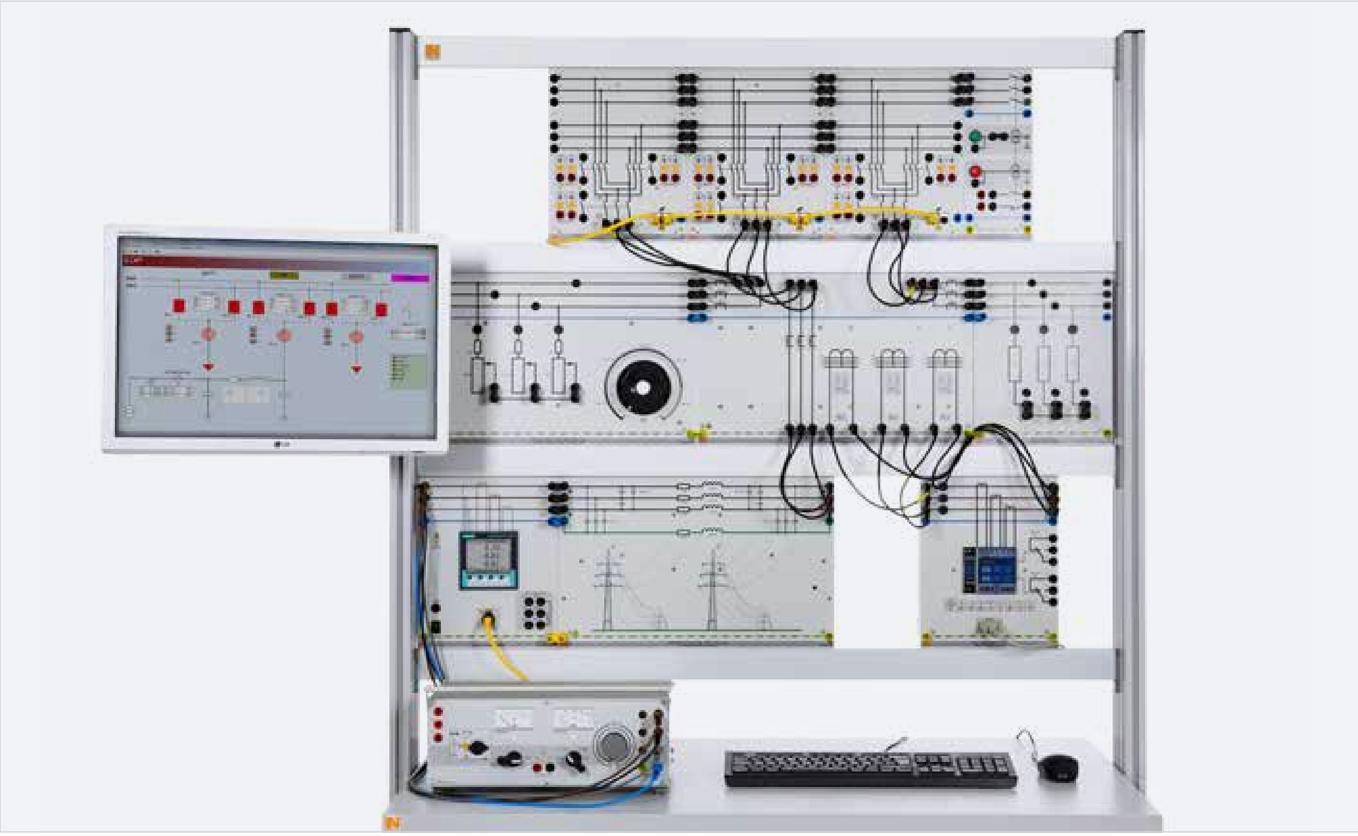
Sample experiment "Three-phase double busbar system" EPD

Training contents

- Basic circuits of a three-pole, double busbar system
- Three-phase, double busbar system with load
- Busbar changeover without interruption of the branch
- Preparation of algorithms for various switching operations
- Busbar coupling

Overcurrent Protection for Busbars

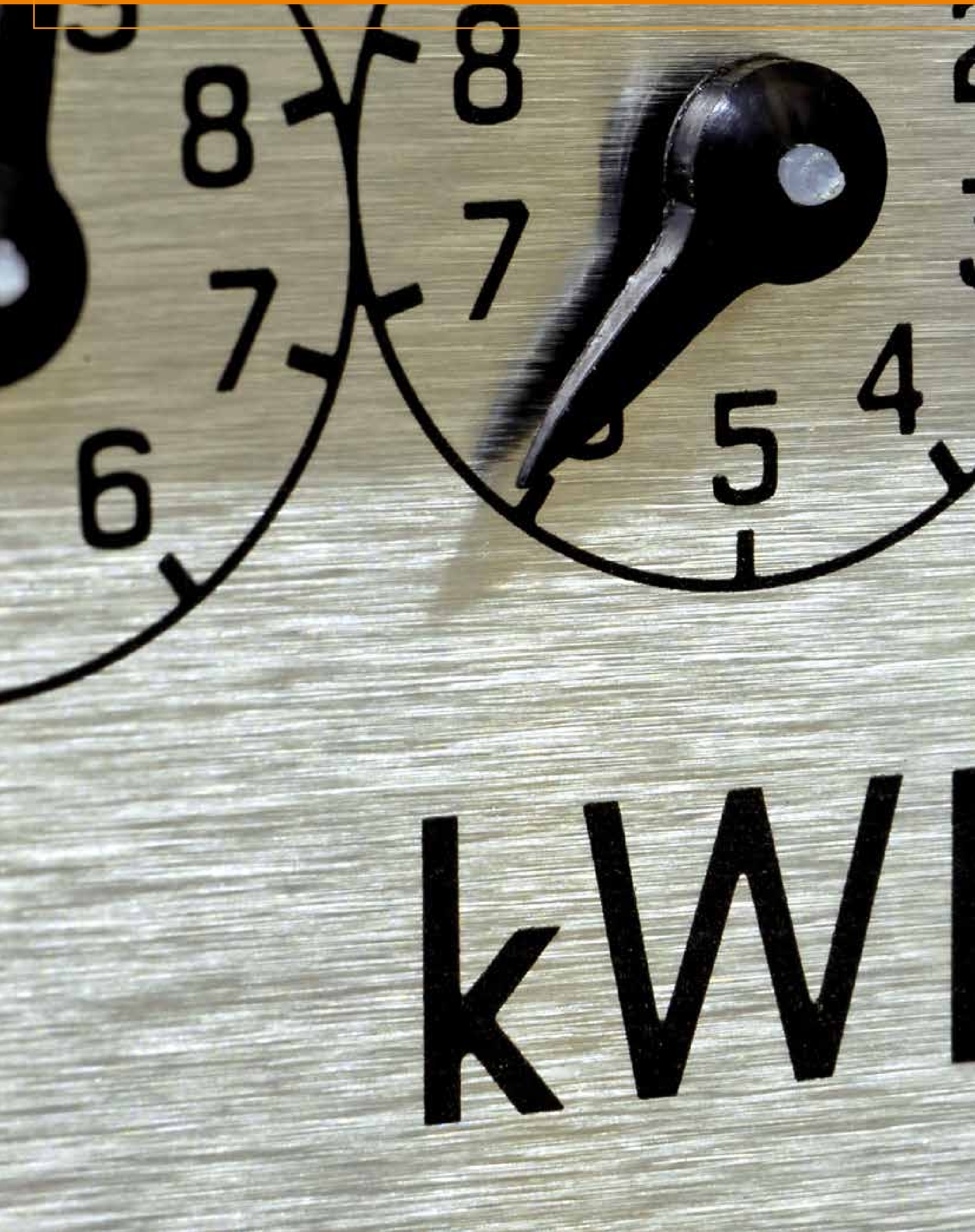
Due to the busbar's differential protection, the input and output currents are added up via a current transformer. In the case of differential currents, the characteristic sensitivity serves as a basis for determining trigger criteria.



Sample experiment "Overcurrent protection for busbars" EDP

Training contents

- Registration of currents in normal operating mode
- Registration of currents in the event of single-, double- or triple-pole short circuit
- Faults outside the protective domain
- Response of protective equipment to faults both external and internal to the switchgear


kW

Energy Management

Energy Management

Intelligent networks and loads

For economic and environmental reasons, a rational use of energy is becoming increasingly important. Exercises on manual and automatic compensation of reactive power as well as experiments on reducing peak loads through measurements with active-current and maximum-demand meters demonstrate how the load on an electricity supply network can be reduced and evenly distributed over a 24-hour period. An analysis of the power supply grid and connected consumers (loads) is necessary for effective use of the involved measurement techniques. Accordingly, each experiment permits a detailed investigation of static, dynamic, symmetric and asymmetric loads. Protection of electrical consumers is another important training subject.

Smart metering

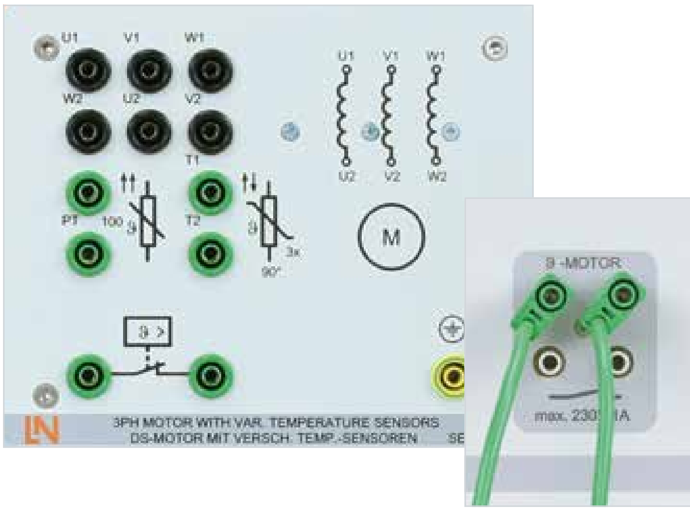
All energy technology kits contain intelligent measuring devices possessing a variety of communication interfaces (e.g. LAN, RS485, USB) and control elements. Consequently, consumers can not only be monitored, but also intelligently controlled. An automatic load management program can be realized with the features listed below:

- Monitoring of the specified power limit
- Enabling and disabling of consumers in accordance with a defined priority list
- Activation of consumers during low-load intervals

Source: SIEMENS

Protecting electrical consumers

Malfunctions in electrical systems resulting from short circuits, overload etc. must be prevented or at least restricted by means of appropriate protective measures, and the faulty devices disconnected selectively from the network. For the protective features to be properly implemented and correctly dimensioned, it is necessary to know their trigger characteristics and times, as well as their operational characteristics. This experiment series provides detailed treatment of how to protect three-phase motors by means of a motor protection switch, temperature monitoring in the coils, and triggering via a thermistor device. An experiment on full motor protection with a digital device can also be conducted. The handling and parametrization of the digital motor protection device are the focus of training in this experiment.



Training systems

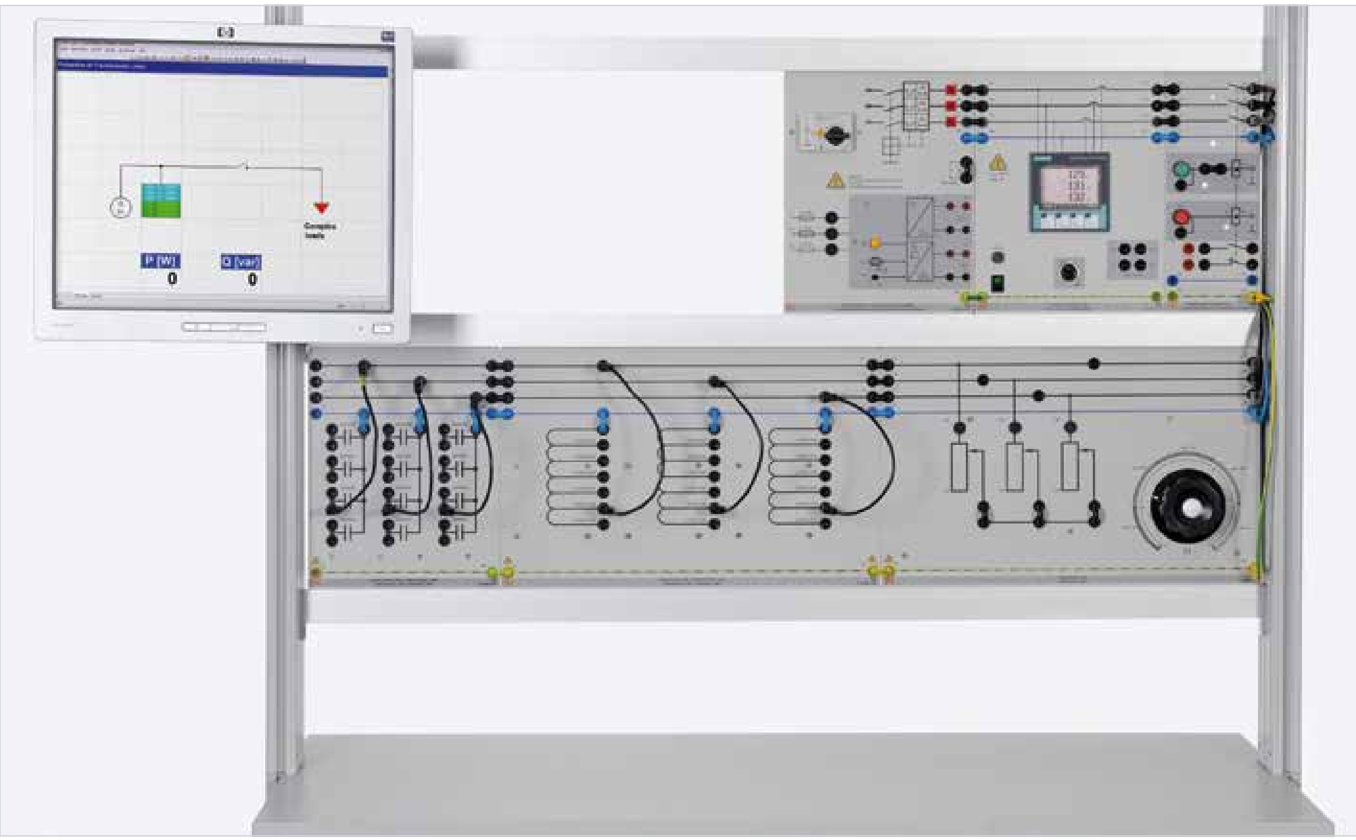
Our training systems cover the following topics:

- Experiment panel group - "Complex loads, energy consumption measurement and peak load monitoring"
- Experiment panel group - "Dynamic loads"
- Experiment panel group - "Manual and automatic compensation of reactive power"
- Experiment panel group - "Protection of electric machines"
- Experiment panel group - "Motor protection/management"

Energy Management

Complex Loads, Power Consumption Measurement and Peak Load Monitoring

Experiments on reducing peak loads through measurements with active-current and maximum-demand meters demonstrate how the load on an electricity supply network can be reduced and evenly distributed over a 24-hour period. An analysis of the power supply grid and connected consumers (loads) is necessary for effective use of the measurement techniques involved. Accordingly, each experiment permits a detailed investigation of static, dynamic, symmetric and asymmetric loads.



Sample experiment "Measuring the power consumption of complex loads" EUC 1

Training contents

- Three-phase consumers with star and delta connections (R, L, C, RL, RC and RLC loads)
- Measurement with active and reactive energy meters:
  - for symmetric and asymmetric RL loads
  - in the event of a phase failure
  - in the event of over-compensation (RC load)
  - for active loads
  - in the event of energy-flow reversal
- Determination of the first and second power maxima
- Determination of the power maximum in the event of an asymmetric load
- Recording of load profiles

Dynamic Loads

In this case, a three-phase asynchronous motor coupled with the servo machine test stand is used as a dynamic load. The active and reactive powers (motor's cos-phi) depend on the motor load and are therefore not constant. The servo machine test stand can also be used to drive the asynchronous motor, thereby feeding active power into the three-phase network.

Sample experiment "Investigations on dynamic loads" EUC 2

Training contents

- Dynamic, three-phase load (asynchronous motor)
- Power measurement in the case of energy-flow reversal

Energy Management

Manual and Automatic Compensation of Reactive Power

Reactive power compensation in alternating voltage networks is designed to reduce undesirable reactive current and resultant reactive power of consumers. In this process, capacitive loads are connected to all inductive loads via a central feed point. The opposing, capacitive reactive power arising here is ideally of the same magnitude as the installed, inductive reactive power. This reduces undesirable reactive currents, and none of the systems needed to supply the reactive current has to be over-dimensioned.

Sample experiment "Automatic compensation of reactive power" EUC 3

Training contents

- Operating an asynchronous machine and recording its characteristic parameters
- Calculating parameters for compensation capacitors
- Compensation using various capacitors
- Determining stage power
- Manual compensation of reactive power
- Automatic identification of a reactive power controller's connections
- Automatic compensation of reactive power

Energy-efficient drives

In Germany, about half the electrical energy the country needs is used by industry. The main consumers are electrical drives. These account for some 70% of industrial electricity consumption. Optimising electrical drives can therefore help to save costs and protect resources. In optimising industrial plant operated by electricity, it is always necessary to examine the whole drive system since there are various factors which affect the energy efficiency of drive motors, such as the intelligent use of electrical power, improvement of efficiency, automatic speed control and energy recovery.

"Energy-efficient frequency converter drives" training system consisting of an optimum-efficiency motor, frequency converter and servo machine test stand EEM11.3

Training contents

Energy-efficient drive design
- Identifying losses in a drive system
- Investigation of motor parameters by means of characteristic curves
- Optimisation of system efficiency by selecting the appropriate motor
- Indirect determination of loading on a motor

Use of energy-saving motors:
- Design and function of energy-saving motors
- Energy efficiency classes for motors
- Comparison between an energy-efficient motor and a standard motor
- Characteristic parameters for energy-saving motors
- Determination of savings potential

Energy-efficient frequency converter drives:
- Setting up variable-speed drives
- Investigation of how various parameters affect operating response
- Energy-efficient matching of operating points
- Creating energy-efficient motion profiles
- Observation of overall system efficiency

Protection of Electric Loads

Effective Motor Protection – Preventive Maintenance

Used as part of modern automation technology, motor management systems make it possible to optimally protect, control and monitor drives and related equipment. Parameters such as motor temperature, voltage and current can be registered in this way. Linkage to higher-level process automation via field bus systems (e.g. PROFIBUS) makes the motor's operation more transparent. As a result, the motor's utilization level and energy consumption can be monitored without having to perform in-situ measurements.

Sample experiment "Motor management relay" EDT 51

Training contents

- PC-supported operation of a motor management system
- Programming of functions such as direct start, star-delta start, reversible-pole motor start, motor protection
- Parametrization of overload variables and switch-off response under various loads
- Measurement of dynamic processes during starting
- Preventive maintenance

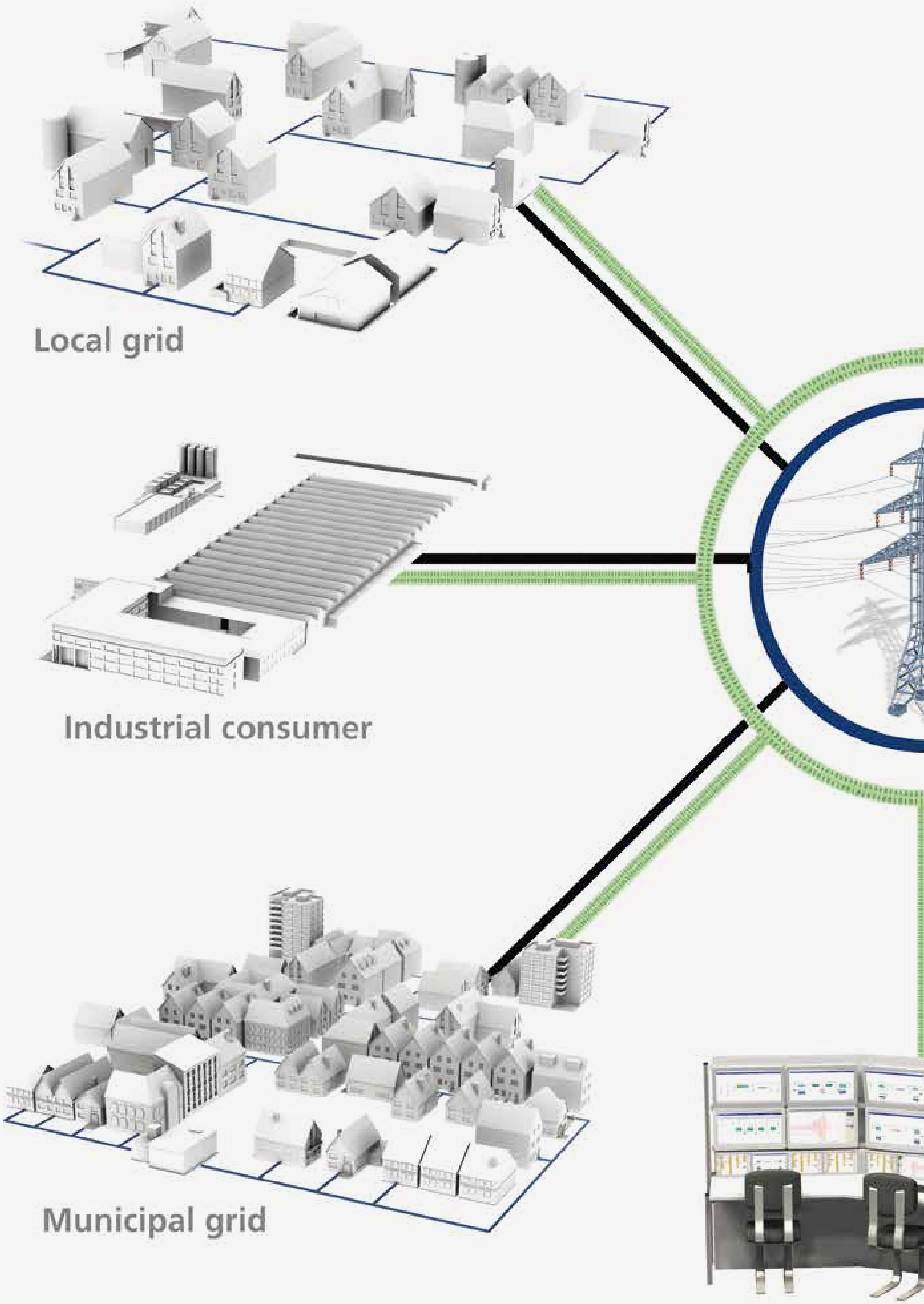
Three-phase Asynchronous Machines

Squirrel-cage motors are designed for operation under constant load conditions. Changes in load or excessively high starting currents can cause such motors to heat up beyond permitted levels. Sensors are therefore used to monitor the motor's temperature and current consumption.
As required, these sensors activate protective features such as the motor protection switch, motor protection relay and thermistor relay.

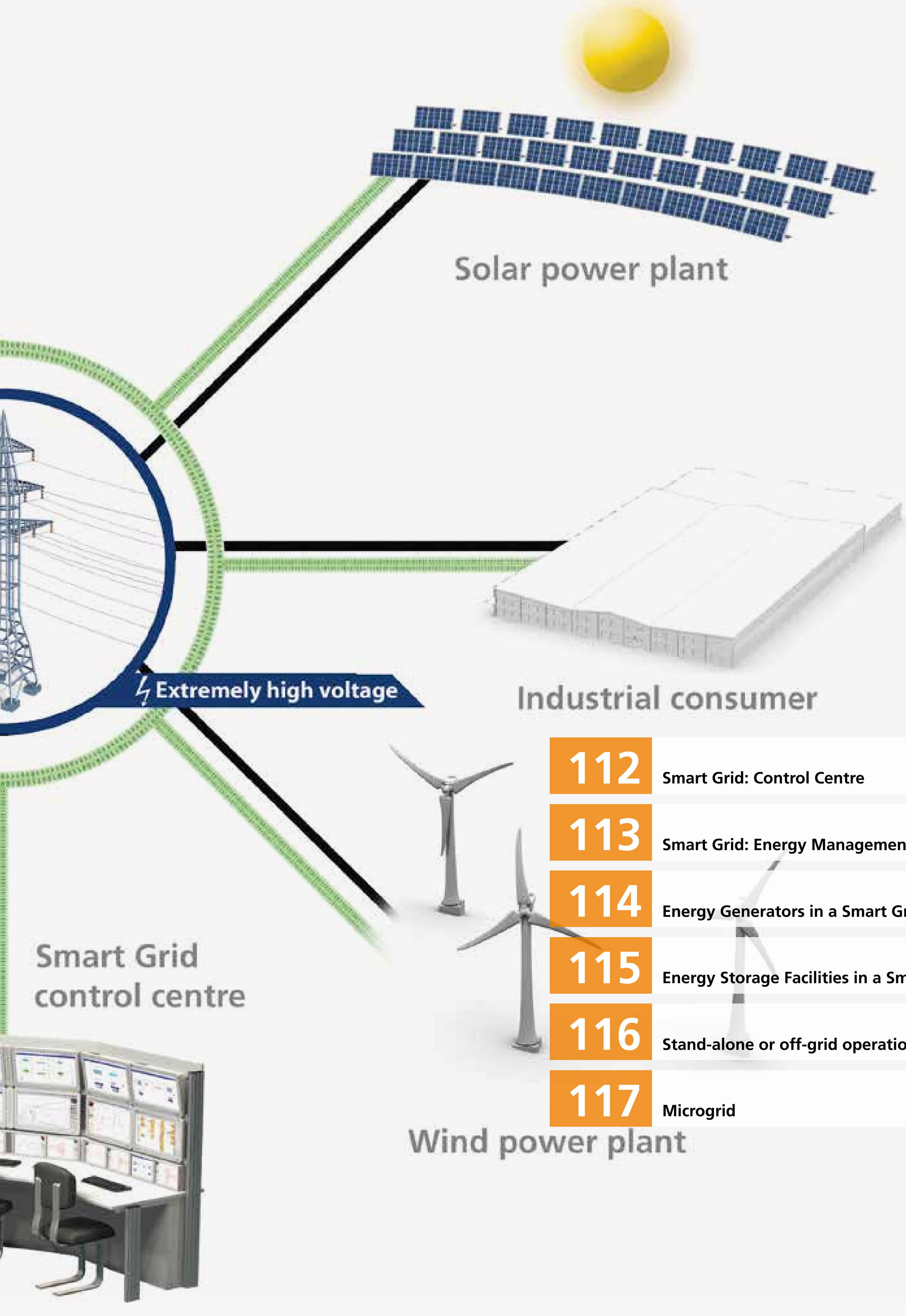
Sample experiment "Protection of electric machines" EEM 4.6

Training contents

- Selecting, installing and setting various motor protection systems
- Motor protection switch
- Motor protection relay
- Thermistor protection
- Effect of various operating modes on motor heating
- Trigger characteristics of protective systems
- Protection against impermissible load states


Local grid
Industrial consumer
Municipal grid

Smart Grid



Solar power plant
Extremely high voltage
Industrial consumer
Smart Grid control centre
Wind power plant

Smart Grid

Ideally Equipped for the Future: A Smart Grid in a Power Engineering Laboratory

In future, new technologies will better equip the power supply grid for the demands of a new era. More flexible network management should make the increasing contribution from renewable energies more compatible with the conventional power station infrastructure. The variety in the nature and number of such decentralised power generation systems requires a new way of running the power grid, a so-called intelligent network or "smart grid":

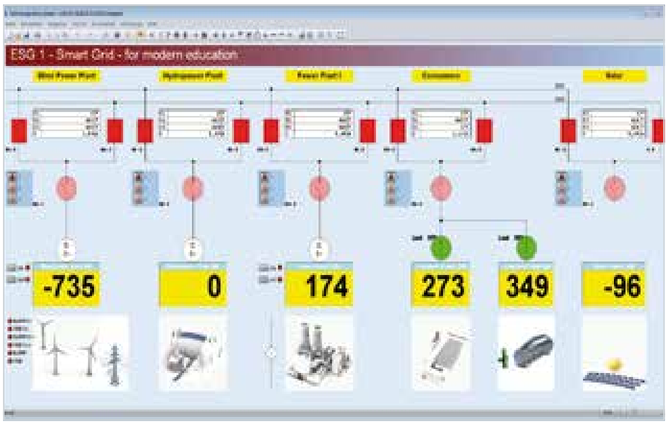
- Improved coordination between energy consumption and generation
- Use of modern information technology, such as the Internet, sensors, control systems and wireless communications equipment
- "Smart metering" – digital electricity meters measure power consumption by end users of the power grid.
- Shifting of household consumption away from peak-load periods
- Automatic starting of flexible applications, such as washing laundry, by energy suppliers themselves outside of peak times

Modular Integration of Regenerative Power Generation into a Smart Grid:

- Photovoltaics
- Wind power
- Storage of electrical energy by means of pumped storage hydroelectricity
- Conventional power generation
- Transmission and distribution
- Energy management (coordination of dynamic power generation and consumption)

SCADA Software in a Smart Grid

- Implementation, control and analysis of complex, intelligent grids (smart grids)
- SCADA software adapted for education
- **SCADA PLC:** Integrated software PLC (IEC 61131)
- **SCADA Logger:** Recording, display, evaluation and export of all values recorded in a given period
- **SCADA Designer:** Symbolic layout of all equipment from Lucas-Nülle's energy supply range on a user interface
- **SCADA Viewer:** Display and control of measurements and status from all computers on the network
- **SCADA Net:** The client/server concept makes it possible to remotely access systems on the smart grid from multiple (student) PCs at the same time.
- **SCADA Panel Designer:** Design your own control panels



Smart measuring instruments:

- Smart measuring instruments with a variety of controls and ability to communicate via various interfaces (e.g. LAN, RS485, USB)
- Measurement and control of all relevant variables by means of smart meters and high-powered switches
- **SCADA Net-compatible:** Display and control of measurements and status from any PC on the network

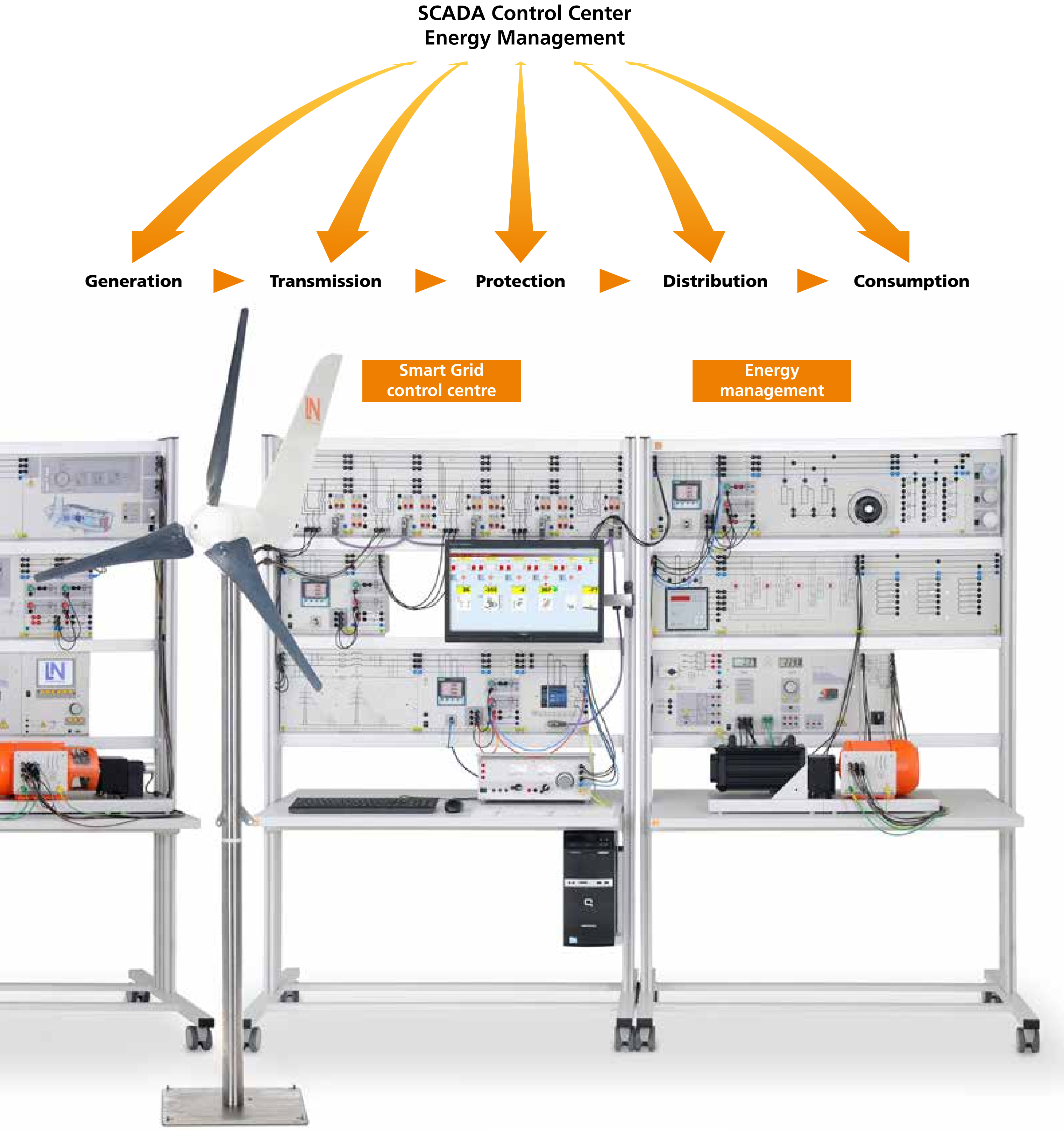
"Smart Grids" – Intelligent Power Supply Networks

The Networked Power Engineering Laboratory

These equipment sets allow training systems covering the generation, transmission and management of electrical energy as well as the protective equipment required to be combined, both electrically and by means of computer networks. All relevant values can be measured via the smart grid Control Centre control centre and the necessary switching operations undertaken. This makes it possible to study the influence of renewable energy generation in laboratories. A host of scenarios can be emulated, such as the following:

- Charging of electric cars when there is a surplus of wind energy
- Storage of excess energy in pumped-storage hydroelectric plants
- Disconnection of consumers to reduce peak load
- Compensating for energy deficits by means of pumped-storage hydroelectric power

The SCADA software allows the whole system to be observed or controlled from any work station

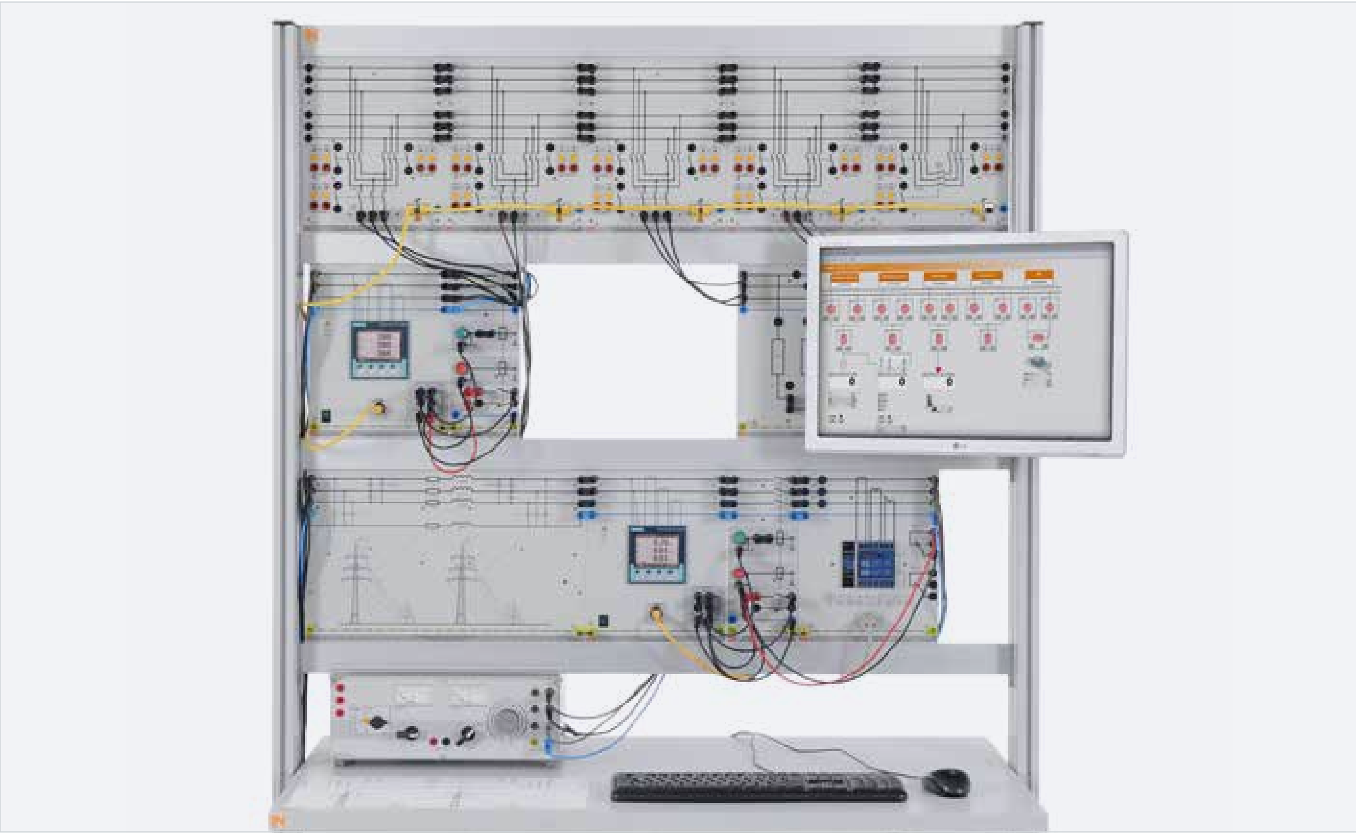


SMART MICRO GRID

"Smart Grids" – Intelligent Power Supply Networks

Smart Grid – Control Centre

This equipment set forms the core for a smart grid in a power generation lab. In addition to generation, transmission and distribution of energy, the SCADA software records all relevant values and handles the requisite switching operations. This can be done manually or automatically by means of a software PLC system.



Example experiment "Smart grid: Generation, distribution and transmission of electrical power ESG 1.1"

Training contents

Three-phase double busbar system

- Basic circuits for a three-pole double busbar system
- Three-phase double busbar systems with load
- Busbar transfer without interrupting feed
- Finding switching algorithms for various switching operations
- Busbar coupling

Investigations on three-phase transmission lines

- Voltage rises in unloaded transmission lines
- Voltage drop as a function of line length
- Voltage drop as a function of cos phi
- Capacitive and inductive power losses in a transmission line as a function of voltage and current
- Phase-shift along the line

Definite time overcurrent protection for lines

- Rating and parameters for definite time overcurrent protection
- Determine returning ratio (differential) for short circuits involving one, two or three poles

Smart Grid – Energy Management

The topic of energy management includes switching off consumers to reduce peak loads as well as reactive load compensation for reducing losses along transmission lines. The asynchronous machine in the set can be dynamically loaded by means of the machine test stand in order to simulate variable changes in load over time on the entire electricity grid. Such changes in load are recorded by the smart grid Control Centre so that suitable remedial action can be taken to keep the grid stable.

Example experiment "Smart grid: Energy management ESG 1.2"

Training contents

Complex loads, metering of electricity consumption and monitoring of peak load

- Three-phase load in star and delta configurations (R, L, C, RL, RC or RLC load)
- Measurements with active and reactive work meters

Dynamic loads

- Dynamic three-phase loads (asynchronous motors)
- Power measurement when energy is being fed in and fed out

Manual and automatic reactive power compensation

- Putting asynchronous machines into operation and recording parameters
- Manual reactive power compensation
- Automatic reactive power compensation

"Smart Grids" – Intelligent Power Supply Networks

Energy Generators in a Smart Grid

These supplementary equipment sets for power engineering can optionally be combined, either individually or in conjunction with the "smart grid" experiment set ESG 1. This makes it possible to conduct extensive investigations in a smart grid.

Example experiment "Smart grid supplement to ESG 1: Energy generators in a smart grid"

Training contents

Wind power plants, EWG 1
- Operating a generator under changing wind speed plus control of output voltage and frequency
- Determining optimum operating points under changing wind conditions

Photovoltaic systems operating parallel to the main grid, EPH 3
- Setup and testing of photovoltaic systems with mains feed
- Measurement of energy generated by a photovoltaic system
- Determining efficiency of grid-connected power inverters
- Voltage control in a local power grid (derating)

Synchronous generators, EUG
- Generator control and synchronisation
- Manually operated synchronisation circuits
- Automatic synchronisation circuits
- Automatic power and power factor correction

Transformers EUT
- Multi-phase transformer operating with no load, with a short circuited secondary, with resistive, inductive and capacitive loads
- Investigation of the transformation ratio

Pumped storage power plant/Power plants

In the power plants course, the way the following types of power plant operate is covered: Lignite power plants, Coal-fired power plants, Gas turbine power plants, Gas and steam power plants, Biogas combined heat and power (cogeneration) plants, Nuclear power plants, Hydroelectric power plants. The pumped storage power plant course analyses how electrical energy can be stored by transforming it into potential energy of water and then transforming it back into electrical energy again for feeding to the grid. Pumped storage plants are becoming increasingly necessary due to the increase in renewable energy generation and also provide indispensable energy storage capacity in a high-quality smart grid.

Example experiment "Smart grid supplement to ESG 1: Pumped-storage hydroelectric plant EUG 3"

Training contents

- Setting up synchronisation
  - Putting a multi-function relay into operation
- Generator operation
- Grid synchronisation
  - Setting parameters for a multi-function relay
  - Automatic synchronisation
- Manual power regulation for generators and motors
- Generator control using SCADA
- Power plants
  - Types of power plant
  - Typical characteristic curves and parameters
  - Commissioning and operation of various types of power station
  - Finding out how power plants work
  - Automatic load following with externally measured active and reactive power
- Pumped storage power plants in a smart grid

Off-grid Control in Microgrid

Stand-alone or off-grid operation

The stand-alone power network is a type of power supply network that is isolated and has no active coupling lines to other grid power systems. An off-grid or stand-alone network is noticeably smaller than an interconnected power grid and as a rule does not incorporate any extra-high-voltage lines. For these kinds of grids, a distinction is drawn between two different operating modes, stand-alone mode and isolated parallel mode. This type of power network is frequently used in industrial power systems found in large-scale businesses.

Experiment example "Isolated mode" EMG1

Training content

- Fundamentals of stand-alone off-grid networks.
- Controlling a generator in an off-grid network.
- Coordinating power consumption (requirements) and generation in an off-grid network.
- Use of modern information technology, e.g. networked sensors/actuators, PLC control systems and SCADA user interfaces
- "Smart Metering" of a balanced node in order to make a subnetwork autonomous.
- Manual control
- Voltage control
- Frequency control

Isolated parallel mode / microgrid

When this off-grid network is coupled to the smart grid it is referred to as a microgrid. This grid has three different operating modes: on-grid, off-grid and dual mode. The microgrid features the following benefits:

- Reduction of transmission and transformer losses
- Independence from large power suppliers (utilities)
- Smart grid as back-up system
- Intelligently controlled power supply and consumption thanks to SCADA
- Power generation with renewable energy sources
- Optimum electrical power quality, reliability and sustainability

Microgrids are playing an ever more prominent role in the smart grids of tomorrow.

Rational complements for autonomous microgrid:
- Photovoltaic advanced (EPH2)
- Wind power plants (EWG1)
- Pump storage power station (EUG3)
- Dynamic consumers (EUC2)

Versuchsbeispiel „Inselparallelbetrieb mit zwei Generatoren" EMG2

Training content

- Control of multiple generators in a stand-alone (off-grid) network
- Control of multiple generators in parallel operating mode
- Coordinating of energy needs and generation inside a stand-alone network
- Use of state-of-the-art information technology like networked sensors/actuators, PLC control and SCADA operating environment
- "Smart Metering" of a "slack bus" or balanced node to make subnetworks autonomous.
- Manual control
- Voltage control
- Frequency control
- Torque control
- Power factor (cos phi) control
- Droop control

Decisive Product Benefits

… ensure Long-term Customer Satisfaction

Herr Prof. Guntram Schultz, Dean at the University of Applied Sciences in Karlsruhe, Department of Electrical Engineering and Information Technology:

"I am a huge fan of electrical power engineering from Lucas-Nülle. The extensive programme facilitates innumerable analyses of such fields as power generation and distribution technology – including grid protection – as well as energy consumption.

Thanks to the modularly designed three-phase training panel system, system relationships can be explored step by step within the experiment.

Moreover, the high potential for expandability facilitates seamless integration of renewable energies into conventional power engineering. No other manufacturer provides a system which demonstrates such flexibility and which can be reconfigured again and again depending on requirements.

A particular advantage is in my view the consistent use of the electrical scale of 1:1000 which enables measurement findings to be compared directly with real measurements. Realistic line simulations at the variable length facilitate the deployment of conventional industrial equipment for reality-based project work in a safe lab environment. The SCADA system enables optimal experiment monitoring and control while data evaluation processes are second to none. The materials which come in the form of multi-media courses are very attractively designed and are popular with students.

Meanwhile the quality of the individual experiment components, combined with a proven didactic concept, are the factors which appeal most to lecturers.

All of this is by way of explaining why we chose Lucas-Nülle. Using the programme as a whole, we can plan the entire electrical power engineering course systematically while familiarising students with typical industrial applications in a focussed manner. "

Individual consultation with Lucas-Nülle

Do you require comprehensive advice or a firm offer?

Then you can contact us using any of the following means:

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Lucas-Nülle is a byword for custom occupational training courses in all of the following areas:

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- Renewable energies
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- Automation technology
- Power electronics, electrical machines, drive technology
- Instrumentation
- Automotive technology
- Fundamentals of electrical engineering & electronics
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- Lab systems

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

Our employees will be happy to advise you.

Further information on our products can be found at the following web addresses:

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