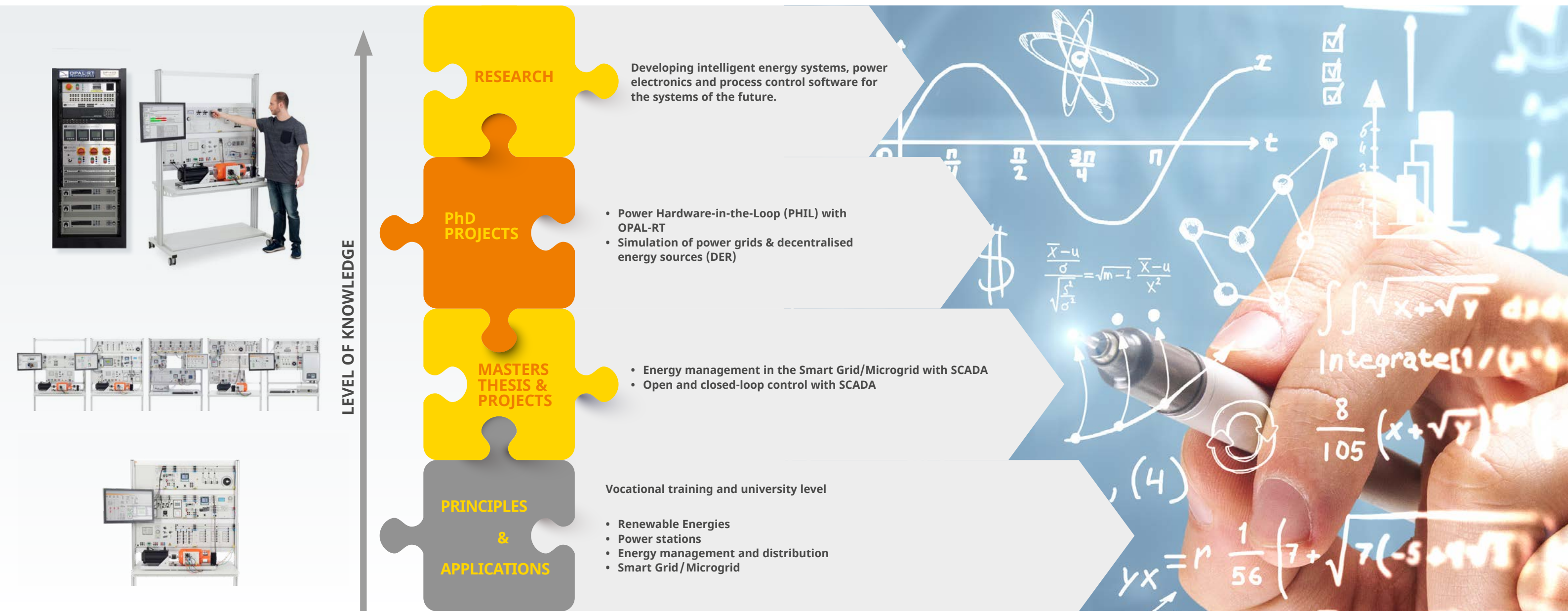


HARDWARE-IN-THE-LOOP

A Training System for Renewable Energies
in Smart Grids, Microgrids and PHIL

FROM BASIC TRAINING TO RESEARCH



The training systems from Lucas-Nuelle are used to cover everything from basic principles up to research and development. That way, acquired know-how and applications developed with the training systems can also be seamlessly integrated into research projects. This means you can do research without having to bother with the cost-intensive and time-consuming business of learning new systems.

Your benefits:

- Fundamentals and applications with digital multimedia course
- Modular systems
- Rapid prototyping systems
- Hardware-in-the-Loop (HIL)
- Power Hardware-in-the-Loop (PHIL)

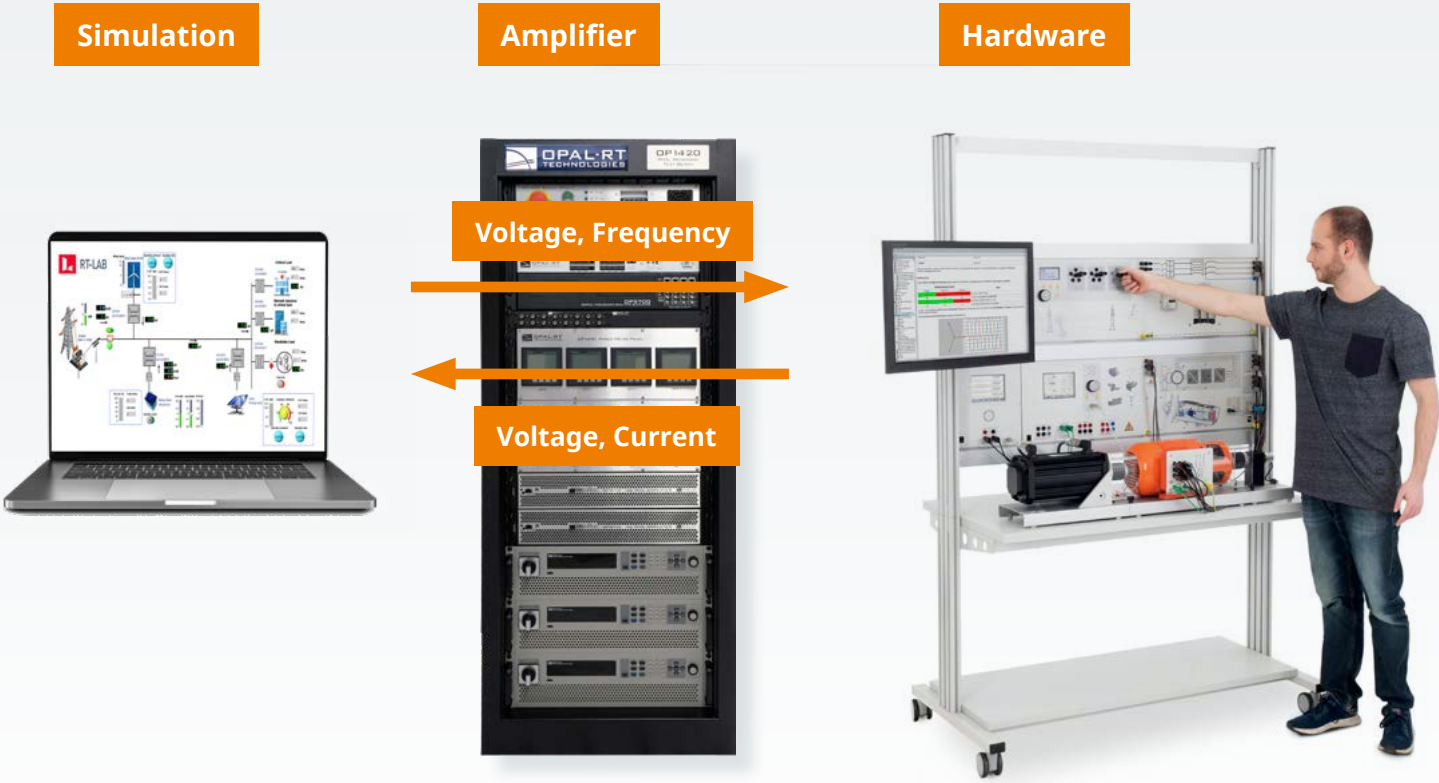
Challenges facing power engineering

New and innovative concepts are needed for system-stabilizing automatic controls and improved strategies for operating power systems.

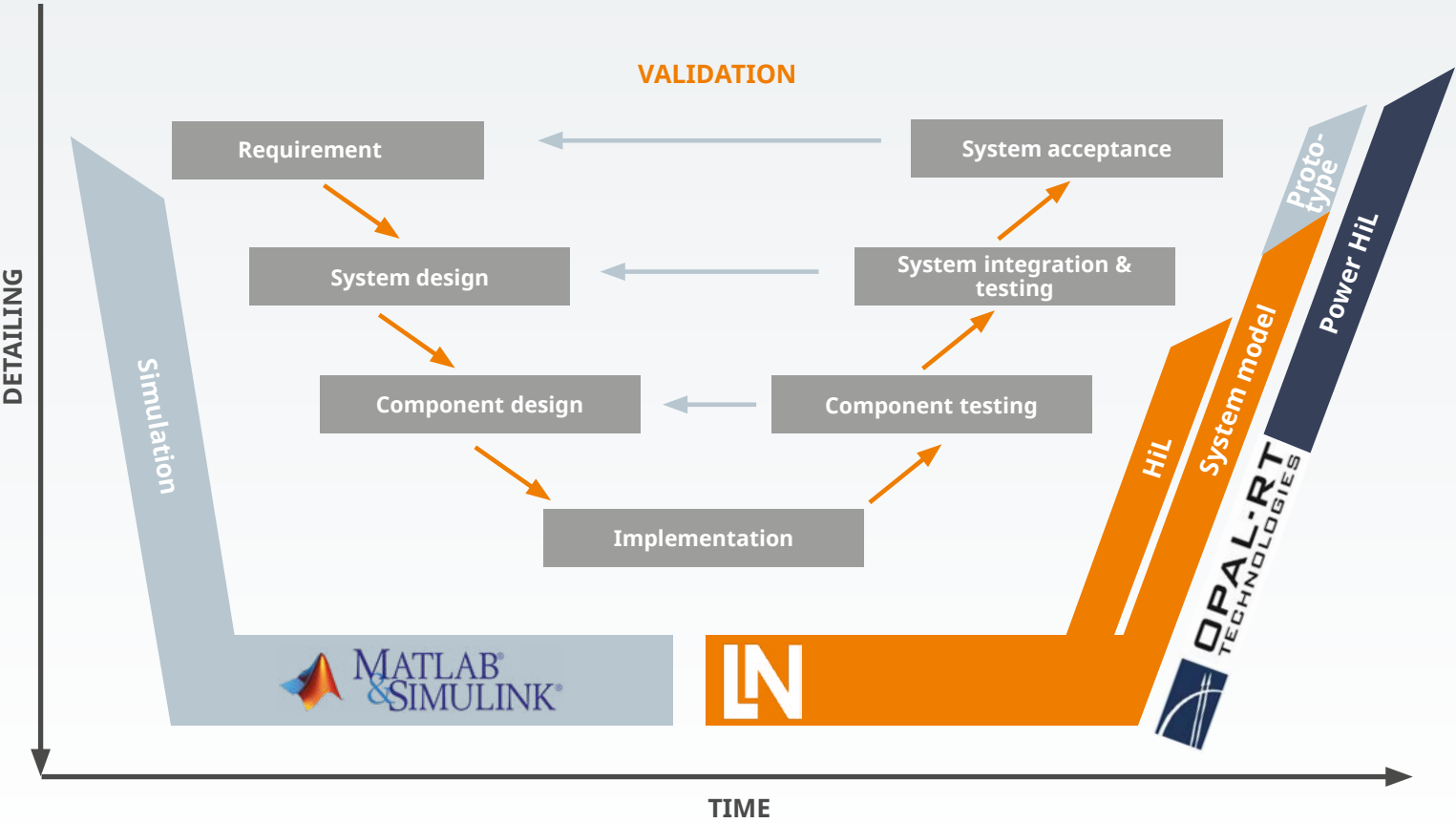
Power grid in transformation

Renewable energies like wind power and photovoltaic systems are frequently based on inverter technology. With more and more renewable energy, the number of fossil-fuelled (large-scale) power stations with synchronous generators will decline. Thus the properties promoting system stabilization in synchronous machines that reduce mechanical inertia also permit reactive power to be made immediately available in large amounts during transient processes brought about by potential short-term overloading.

POWER-HARDWARE-IN-THE-LOOP (PHIL)



Note: This image has been significantly simplified



Power-Hardware-in-the-Loop (PHIL)

PHIL is an expansion of the Hardware-in-the-Loop (HIL) tests, in which the real-time simulation environment is able to exchange power with the DUT (device under test). The DUTs are connected to the simulator via a power amplifier which is controlled by the simulation.



- Fast simulation of power grids, energy sources and distributed energy sources (DER)
- Development of energy systems, power electronics and process control software
- System validation prior to installation into productive systems

Using training systems in the research and development process

Using simulations, many design choices can be made at the very beginning of the development phase. During implementation, these decisions have to be validated for quality assurance purposes.

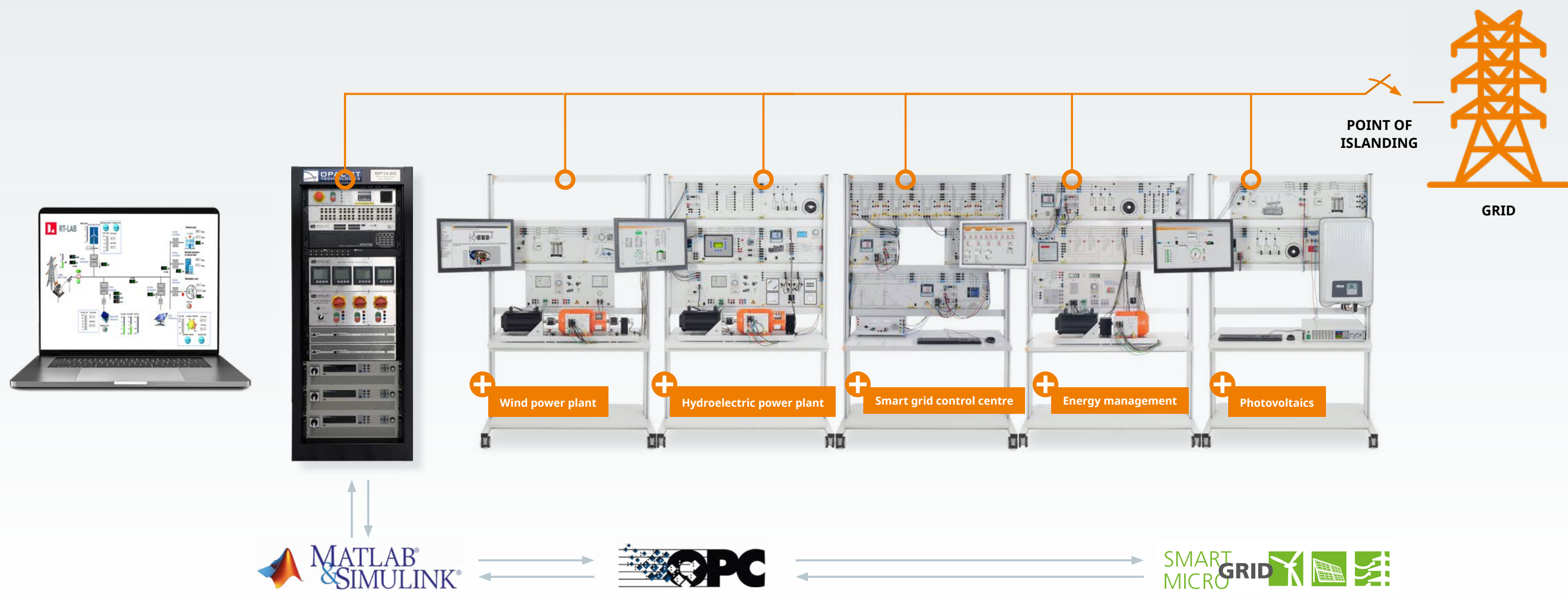
Benefits with Lucas-Nülle training systems

- Modular system
- Simple configuration
- Rapid prototyping systems / Hardware-in-the-Loop (HIL) with Matlab Simulink
- Smart Grid/ Microgrid system models

In conjunction with OPAL-RT

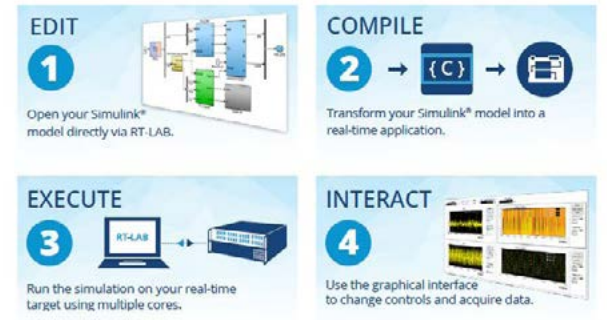
- Power Hardware-in-the-Loop (PHIL)

SMART GRID AND PHIL WITH OPAL-RT



OPAL-RT RT-LAB

Easy to commission and configure parameters in 4 steps



OPAL-RTOP1420 – Power amplifier

- 4Q Power amplifier up to 15 kW
- Innovative soft-switching cell based on SiC transistor technology
- 100% energy recovery, no power losses
- Very high efficiency >96%
- Voltage and current mode
- Up to 10 kHz (-3dB), THD
- Microgrid Simulink Model
- FPGA real-time simulation possible
- Microgrid-grid emulator with busbar and measuring devices
- Safety measurement connections
- Protection against overloading, short-circuit and with temperature monitoring

Lucas-Nuelle Smart Grid – Networked Systems in the Power Engineering Laboratory

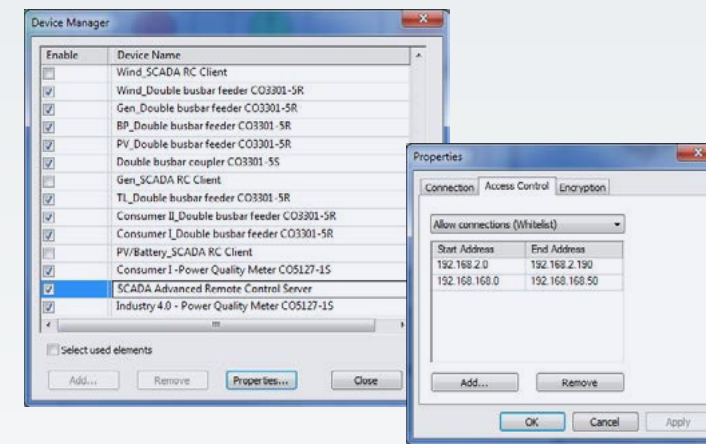
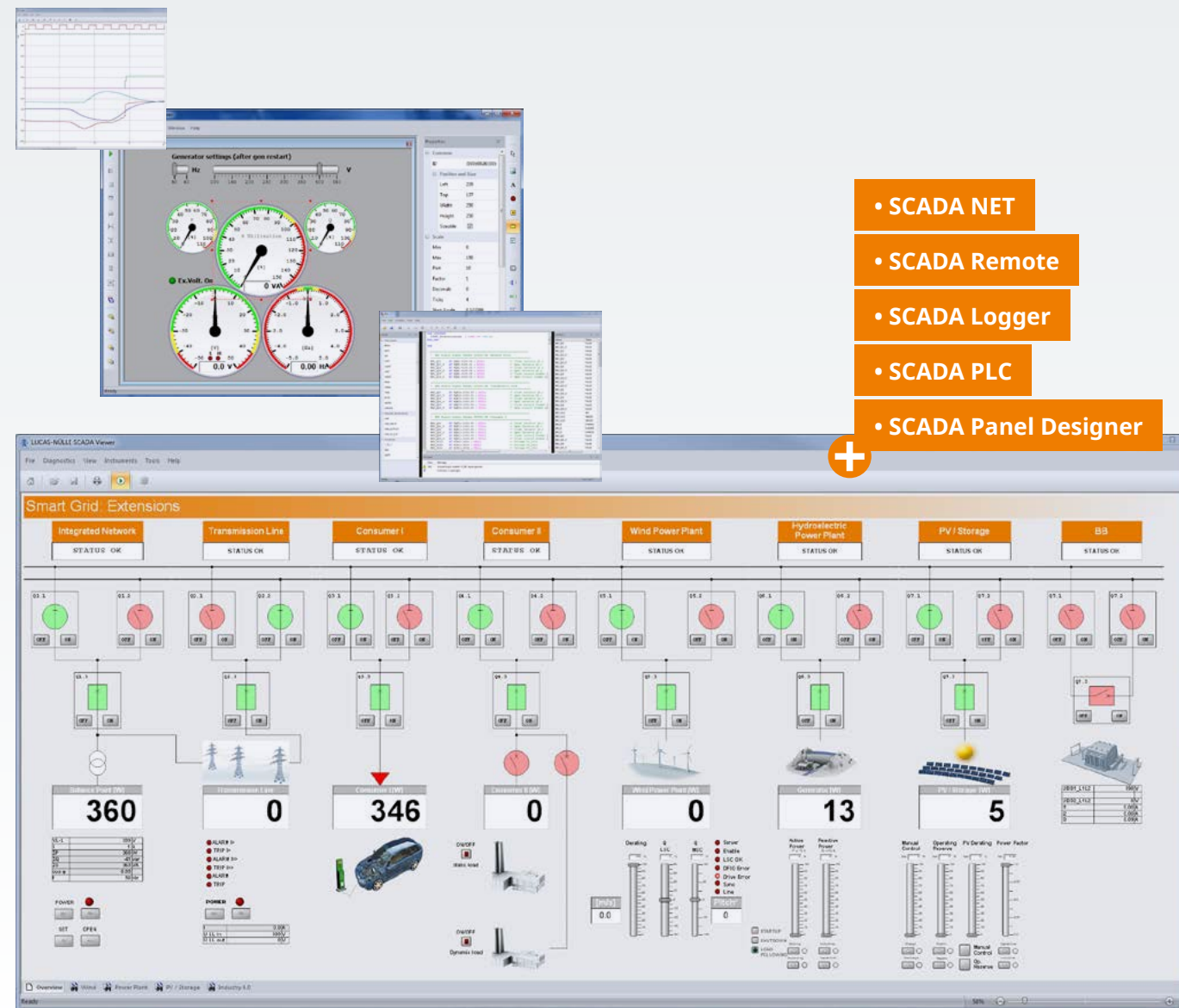
Simulation of an entire power supply grid from energy generation all the way to end consumer

- Renewable energies with fluctuating power generation
- Power distribution with transmission lines, transformers and double busbars
- Systems, measurement and protective devices integrated in SCADA
- Centralized evaluation and control using SCADA
- Unlimited potential for design and investigation of smart grids and power systems in the lab

Smart grid and power amplifier

- Benefits:**
- Realistic training systems for training fundamental principles and applications
 - Combination of simulation, real and industrial hardware
 - Modular design means rapid configuration and adaptation
 - Fast and easy PHIL implementation
 - Fault-protected hardware
 - Pre-assembled models for fast immersion into PHIL

SCADA FOR POWER LAB



- SCADA Client Server
- SCADA OPC
- SCADA IEC 61850

OPC Client

LN OPC Server for SCADA

Group	Name	Type	Value	Quality	Timestamp	Access	ID
Group 1	[00] Apparent current in phase L1	LREAL	0	Good	01.12.2017 15:32:25	R	[07] Time Over Current Relay CO3301-4I[00][00] Apparent current in phase L1
Group 1	[01] Apparent current in phase L2	LREAL	0	Good	01.12.2017 15:32:25	R	[07] Time Over Current Relay CO3301-4I[00][01] Apparent current in phase L2
Group 1	[02] Apparent current in phase L3	LREAL	0	Good	01.12.2017 15:32:25	R	[07] Time Over Current Relay CO3301-4I[00][02] Apparent current in phase L3
Group 1	[03] Voltage V1.1-N	LREAL	233.085	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][03] Voltage V1.1-N
Group 1	[04] Voltage V1.2-N	LREAL	232.302	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][04] Voltage V1.2-N
Group 1	[05] Voltage V1.3-N	LREAL	236.663	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][05] Voltage V1.3-N
Group 1	[06] Voltage V1.1-L2	LREAL	402.8105	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][06] Voltage V1.1-L2
Group 1	[07] Voltage V1.2-L3	LREAL	398.550	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][07] Voltage V1.2-L3
Group 1	[08] Voltage V1.3-L1	LREAL	398.557	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][08] Voltage V1.3-L1
Group 1	[09] Current L1	LREAL	0.17295	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][09] Current L1
Group 1	[10] Current L2	LREAL	0.146506	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][10] Current L2
Group 1	[11] Current L3	LREAL	0.13473	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][11] Current L3
Group 1	[12] Neutral Current	LREAL	0.12054	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][12] Neutral Current
Group 1	[13] Apparent power L1	LREAL	40.4696	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][13] Apparent power L1
Group 1	[14] Apparent power L2	LREAL	34.0342	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][14] Apparent power L2
Group 1	[15] Apparent power L3	LREAL	30.5392	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][15] Apparent power L3
Group 1	[16] Active power L1	LREAL	22.8001	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][16] Active power L1
Group 1	[17] Active power L2	LREAL	-8.66728	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][17] Active power L2
Group 1	[18] Active power L3	LREAL	-9.27730	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][18] Active power L3
Group 1	[19] Reactive power L1	LREAL	-8.54271	Good	01.12.2017 15:33:04	R	[08] BP-Power Quality Meter COS127-15[00][19] Reactive power L1



• SCADA Viewer | Designer

- Custom configurable user interface
- All Lucas-Nuelle power engineering equipment symbolically represented and arrayed
- Standardized electronic circuit symbols for clear visualization of the circuitry
- Individually configurable value lists to display any relevant measurement value
- Display of measured values and operating states in real time
- Implementation and analysis of intelligent power networks (Smart Grid)
- Design of several worksheets per system

• SCADA Logger

- Recording diagrams of the measured values and signals over time
- Editing, analysing and exporting the diagrams
- Measuring the values

• SCADA Panel Designer

- Design and configuration of user interfaces

• SCADA Remote Client / Server

- Monitoring and operating all systems at every PC in the laboratory
- The power engineering lab in the cloud

• SCADA OPC Client

- Connection to external devices, e.g. PLC
- OPC DA V2.02

• SCADA OPC NET Server

- Real-time connection, e.g. to the MATLAB®/Simulink® and LabVIEW via the OPC-Server

• SCADA PLC

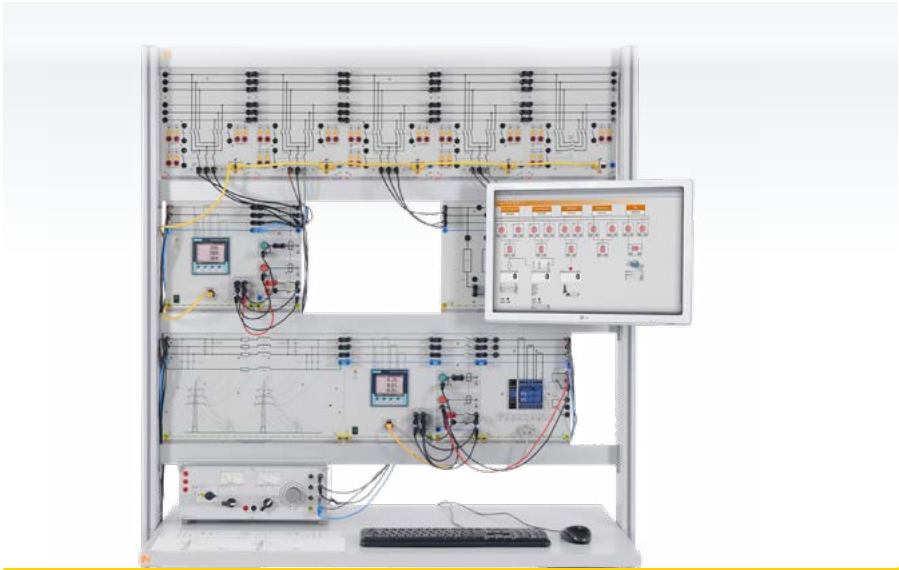
- Integrated Soft PLC (IEC61131 compliant)
- Access to all values and signals in the smart grid
- Automatic generation of the variable lists
- Monitor variables

• Other supported protocols include:

- SCADA IEC 61850 Client (Links up external devices, e.g. PMU)
- TCP/IP Client/ Server
- MODBUS
- SML (Smart Message Language)
- HTTP

Ready-made sample files (templates) are available for all experiments of the multimedia courses.

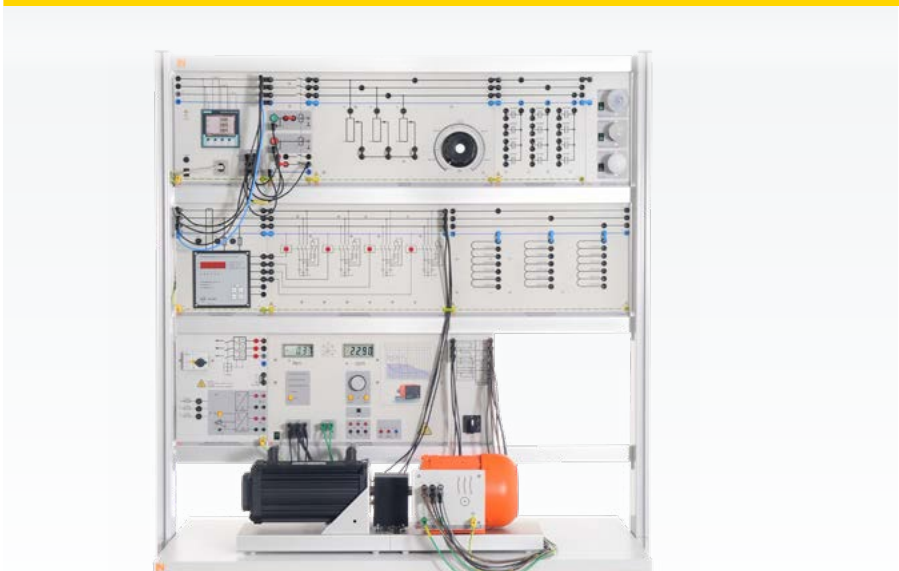
SMART GRID | MICROGRID SYSTEMS



Smart Grid - Control centre

Training contents

- Three-phase double busbar system
- Investigating three-phase power lines
- Overcurrent time protection for power lines



Smart Grid - Energy management

Training contents

- Complex loads, power consumption metering and peak load monitoring
- Manually operated and automatic reactive power compensation
- Load management - Demand-side management



Modern PV systems in parallel operation with power grid

Training contents

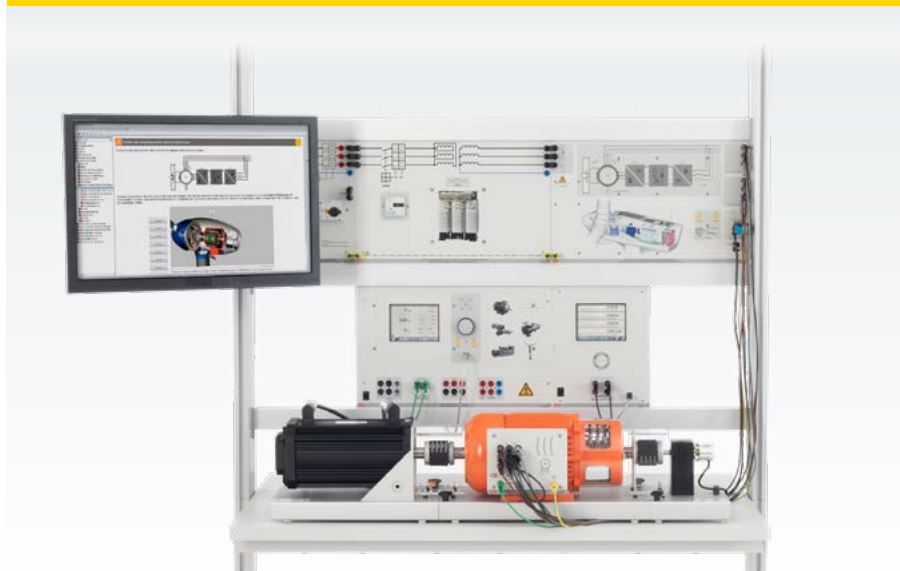
- Measurement of the power generated by a PV system
- PV inverter power limiting (derating)
- Determining the efficiency of the grid inverter
- Control response of the grid inverter, MPP tracking
- Recording magnitude data using the solar path emulator



Pumped storage power station / Power stations

Training contents

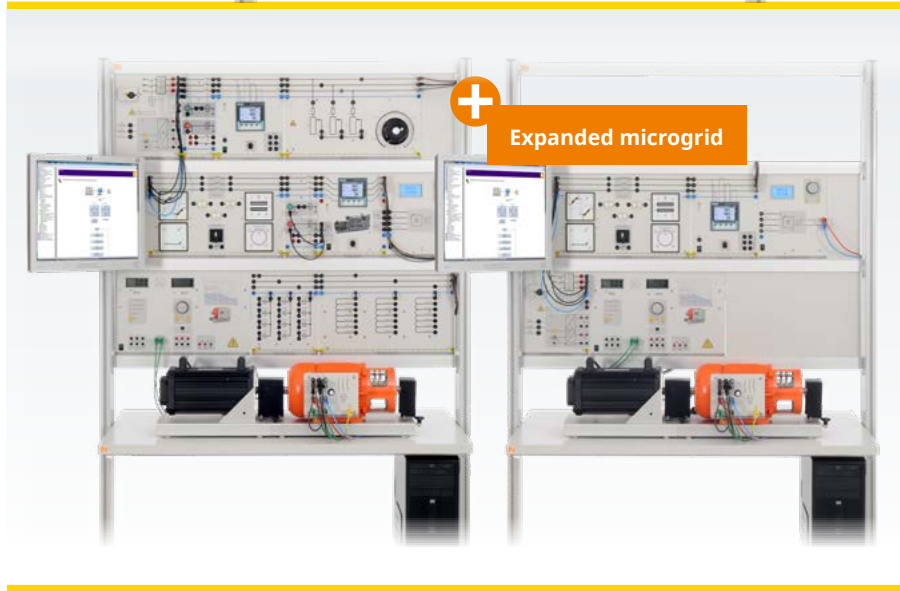
- Synchronisation mechanism
 - Putting the multifunction relay into operation
- Generator operation
- Mains grid synchronization
 - Configuring the parameters of a multifunction relay
 - Automatic synchronization
- Manual power regulation: generator and motor modes
- Automatic generator control using SCADA



Double-fed asynchronous (induction) generators (DFIG)

Training contents

- Understanding the design and operation of modern wind power plants
- Exploring the physical principles of "from wind to shaft"
- Become familiar with various wind power plant concepts
- Design and commissioning of a double-fed induction generator



Island parallel operation Microgrid

Training contents

- Automatic control of several generators in off-grid (island) operation
- Automatic control of several generators in mains parallel operation with grid
- Coordination of power requirement and generation in island (offgrid) mode
- Use of modern information technology, e.g. networked sensor/ actuator configurations, PLC control and SCADA user interface



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