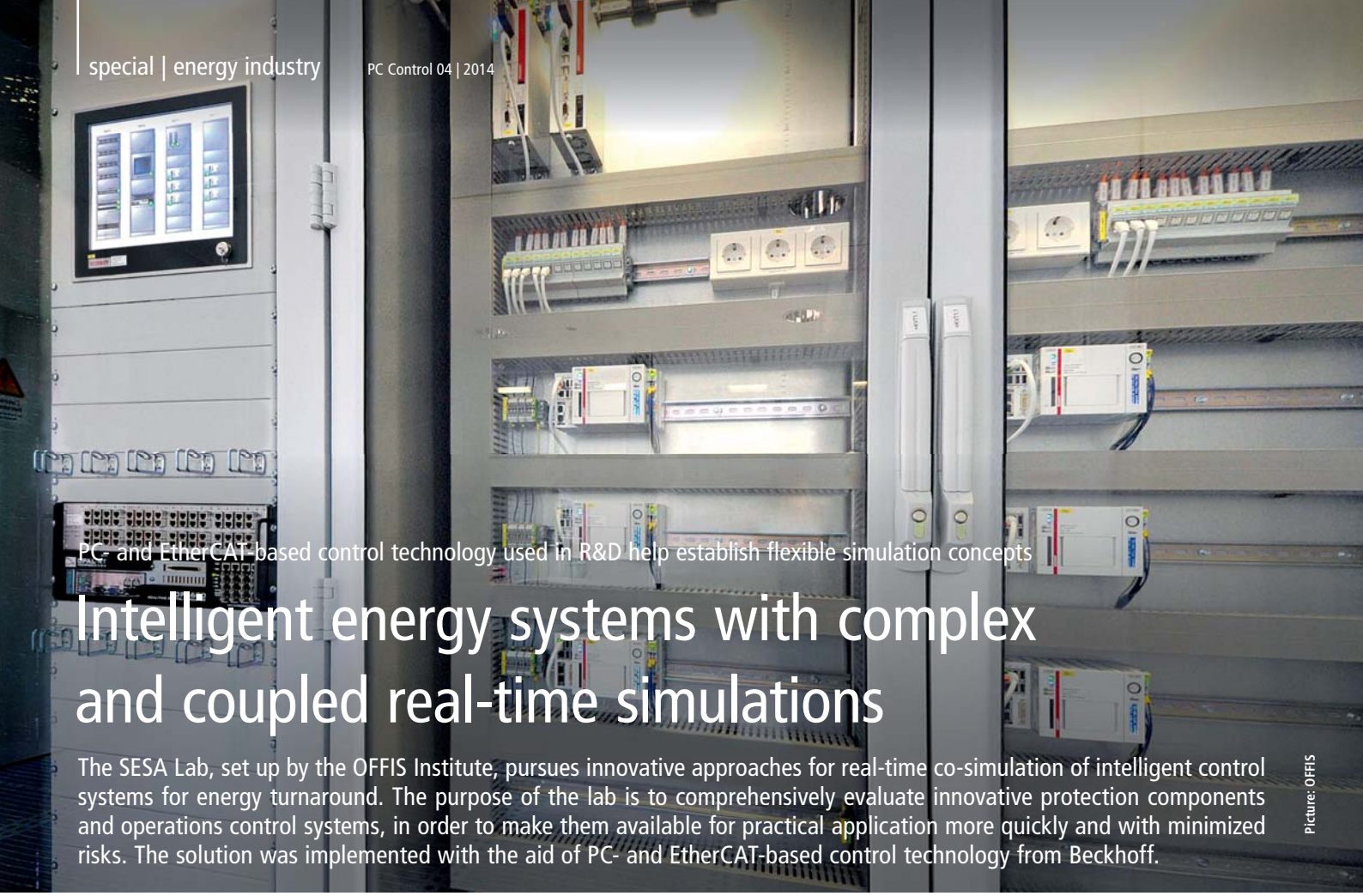


PC- and EtherCAT-based control technology used in R&D help establish flexible simulation concepts

Intelligent energy systems with complex and coupled real-time simulations

The SESA Lab, set up by the OFFIS Institute, pursues innovative approaches for real-time co-simulation of intelligent control systems for energy turnaround. The purpose of the lab is to comprehensively evaluate innovative protection components and operations control systems, in order to make them available for practical application more quickly and with minimized risks. The solution was implemented with the aid of PC- and EtherCAT-based control technology from Beckhoff.

Picture: OFFIS

I/O hub with EtherCAT backbone (left) for topology-free linking of the analog inputs and outputs of the real-time grid simulator (right).

The Smart Energy Simulation and Automation Laboratory (SESA Lab) is part of an integrated "ICT for Energy Efficiency" laboratory infrastructure, a large-scale research facility sponsored by the German federal government and the federal state. Implementation of the laboratory, which is intended for research and education, started at the end of 2013 in the Department for Computer Science at the University of Oldenburg, with significant support from the energy R&D department at OFFIS Institute for Information Technology, based in Oldenburg, Germany.

ICT application in safety-critical energy systems

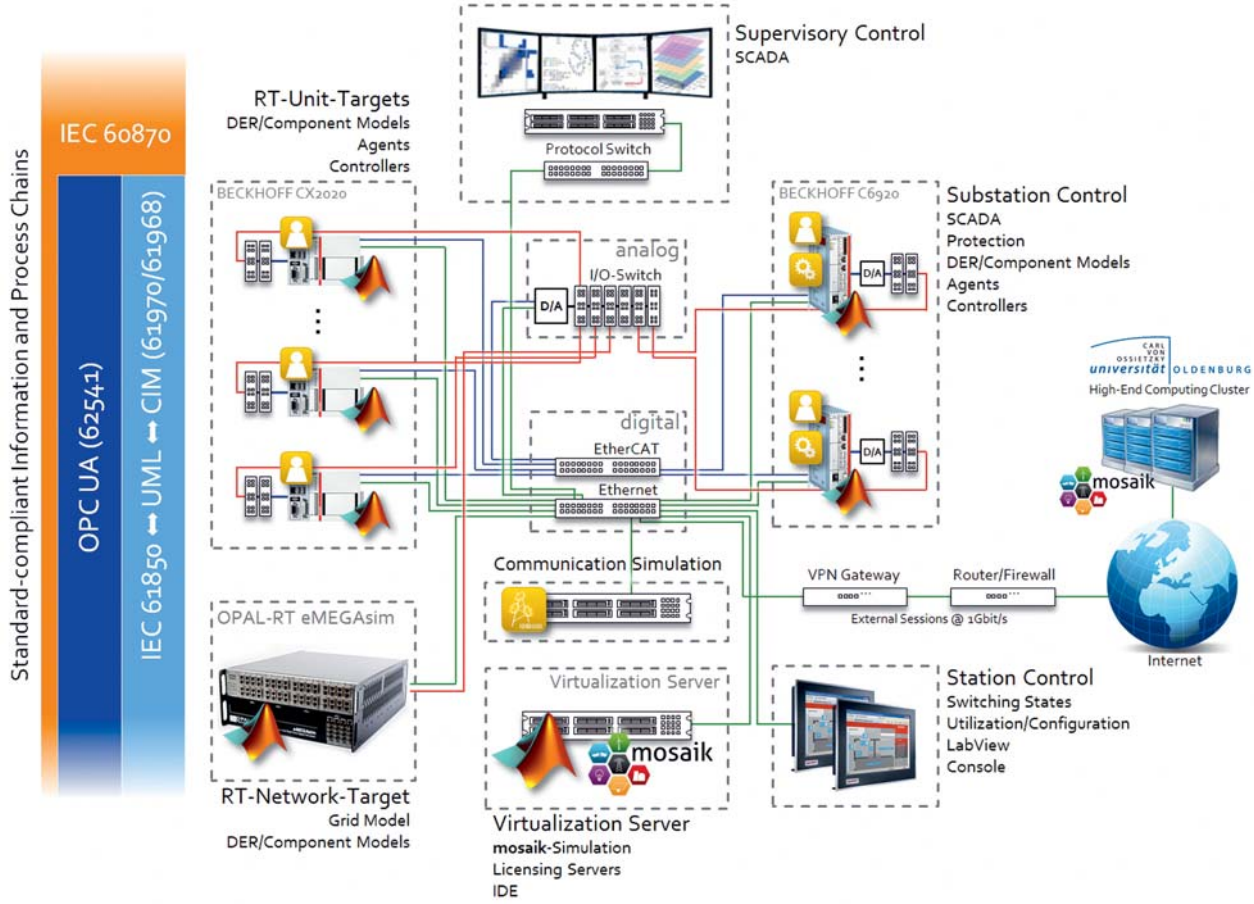
The intelligent energy systems of the future will have to master the challenges of integrating a wide range of active components on a superordinate control level and automatically coordinate them during ongoing operation. This is the only way to ensure safe and reliable operation, while at the same time pushing ahead with the massive expansion of renewable energies, which are inherently variable and therefore subject to forecasting uncertainty.

Although the required information, communication, and automation systems have proven to be reliable in other areas of application, their long-term application in safety-critical energy systems has so far remained largely untested. This means that they introduce a high degree of risk from an energy supply perspective. Innovative ICT solutions for the operational management of decentralized renewable energy systems – e.g. protection and control systems or components for system-side grid-stabilizing power control (active and reactive) – therefore have to be tested extensively in advance, and their interaction has to be assessed.

Flexible simulation concepts are in demand

The high complexity of safety-critical energy systems means that formal analysis to determine certain features is not possible. On the other hand, field tests that would map all influencing factors in a realistic manner would require excessive effort and are therefore not feasible. Simulation is therefore the only adequate option, so environments used for this purpose must be able to integrate a wide range of heterogeneous models that were developed in different contexts. Researchers at the SESA Lab are creating a platform that is able to integrate such models functionally and execute them in a wide range of problem and application contexts.

Such complex and extensive systems cannot be simulated consistently with an accuracy and resolution that enables a valid examination of relevant dynamic processes and control responses (oscillations, harmonics, responses to error situations, etc.) For higher-level balancing studies (e.g. schedule control, market interactions), on the other hand, it is usually not necessary to consider such phenomena. According to Prof. Dr. Sebastian Lehnhoff, who heads the Energy section at OFFIS, this is the reason why the SESA Lab is developing a co-simulation framework under the name of "mosaik", which can be used for automated composition of heterogeneous models and their coordinated simulation.



Picture: OFFIS

Schematic diagram of the SESA Lab.

Co-simulation of precise real-time hardware and generalized software models

At the core of the SESA Lab is a real-time grid simulator. It executes components of ICT and automation systems for future smart grids based on the "hardware-in-the-loop" (HIL) concept. This is already used in the automotive industry to examine dynamic behavior with maximum resolution. Enabling dynamic real-time simulation, "mosaik" combines and coordinates with slightly generalized software-based simulation models. In this way, it makes targeted decoupling of subsystems possible, which can then be examined further in the hardware simulation and automation part of the laboratory.

The real-time grid simulator enables the implementation of high-precision, dynamic grids and resource models on dedicated signal processors. The dynamic or transient behavior of an electrical AC system can be examined with a resolution of up to 10 µs (max. 100 kHz). The grid simulator has analog interfaces to which the AC signals from the grid are connected, which enables HiL operation of actual devices and systems.

Embedded platforms and "topology-free" I/O linking

In addition to the grid simulator, the laboratory uses C6920 control cabinet Industrial PCs (IPCs), CX2020 Embedded PCs and EtherCAT Terminals, all from Beckhoff. Prof. Dr. Sebastian Lehnhoff explains: "This PC-based control technology is used to execute the system and component models based on MATLAB®/Simulink® in real-time. TwinCAT 3 is used as the automation software suite, including a wide range of TwinCAT 3 functions that support, for example, OPC UA, IEC 60870-5-10x, IEC 61850, and IEC 61400-25. The ability of TwinCAT 3 to seamlessly integrate MATLAB®/Simulink® and use it as a programming language to facilitate the integration of corresponding models is a considerable advantage for us. In addition, PC Control as an industrial control technology makes integration of simple controllers or even higher-level, agent-based controllers quite straightforward. The high-performance IPC systems are also used as computer terminals for control and protection system applications.

According to Prof. Dr. Sebastian Lehnhoff, a special feature of this configuration is topology-free linking and allocation of component inputs and outputs within the laboratory: "We use Ethernet- and EtherCAT-based communication for this purpose. On the other hand, we are also able to virtually link the analog inputs and outputs of the real-time platforms, which enables flexible linking of the dynamic system models with different nodes of the real-time simulation without significant conversion effort."

Further information:
www.offis.de
www.beckhoff.com/TwinCAT3