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Research

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ENERGIE
CAMPUS
NÜRNBERG

The research community of the Energie Campus Nürnberg is developing new technologies for an integrated energy system based on renewable energies.

Opening remarks from the Bavarian State Government

We initiated the Energie Campus Nürnberg (EnCN) as one of the fundamental structural policy measures, following the Quelle bankruptcy, to strengthen the region's existing science and economic competency in the energy sector. Since then the EnCN has turned into a remarkable success story. A former industrial wasteland turned into a pulsating area of public life and science. A decisive success factor is the close cooperation between the research partners in the EnCN: Friedrich-Alexander-University Erlangen-Nuremberg, Nuremberg Institute of Technology, three Fraunhofer-Institutes and the Bavarian Center for Applied Energy Research.

Through application-oriented research, companies cooperating with the EnCN now have the opportunity to directly introduce their newly developed products and technologies to the market. To ensure that the investments in the initial phase come to full fruition the Bavarian government has committed to fund the EnCN for a further period of five years. With this considerate backing we support the transfer of the initial structural policy measures into a research which will be able to finance itself in the medium term.

With the continued support, the metropolitan region of Nuremberg-Erlangen will be, along with Munich, the Bavarian energy research location, with both scientific excellence as well as thematic broadness. We expect further positive feedback between the multiple institutions. The EnCN scientists and their research teams strongly contribute to the "Energiewende" energy policy, and with that to one of the most urgent tasks facing the global community in the coming years. We wish continuing success for the future.

Munich, December 2016

Ilse Aigner
Bavarian State Minister of Economic Affairs and Media, Energy and Technology

Dr. Ludwig Spaenle
Bavarian State Minister of Education, Science and the Arts

Founding partners:

FAU Friedrich-Alexander Universität Erlangen-Nürnberg · Technische Hochschule Nürnberg Georg Simon Ohm · Fraunhofer · ZAE Bayern

Our Competences
Value-Added Energy Chain

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Renewable Energy

The research field of renewable energy production generates new materials for solar thermal, photovoltaic and photochemical conversion solar energy through application-oriented development. In addition, printing processes of various photovoltaic technologies and ageing procedures are developed. Our work is conducted in a competence center for printing that is unparalleled in the world.

Energy Storage

In this field, storage technologies, procedures and components are developed that are essential for renewable-based energy systems. The focus is on chemical and thermal storage systems, as well as electrical. In our “Speichertechnikum“ we can simulate and test these developments under real-life conditions.

Electricity Networks

Under networks and infrastructure, new concepts for smart grids are developed. The emphasis is on complete systems as well as components, products and applications specific to innovative and complex power electronics. According to requirements, we conduct high-voltage tests, material inspections, simulations, full-scale demonstration tests and prototype development.

Energy Management Technology

In the research field of energy management systems, new communication networks and system architectures are developed. Priorities include integrating security procedures in data communications and the development of flexible and cost-effective communication platforms with a wide range of applications. Furthermore, tools for simulation and optimization are developed on various levels to support the efficiency of complex energy systems that can be analyzed and managed.

Efficient Energy Use

Within the research area of efficient energy use, not only new materials for thermal insulation are developed, but also new technologies and systems in building engineering. The results can be simulated and tested on a pilot-plant scale and verified.

In the industry sector, new drive concepts are developed and existing systems and products can be optimized and refined. Measurements made on our 400 kW motor test-bench system and simulations provide input for our product and system improvements.

Energy Market Design

Energy market design involves investment incentives for power plant and electrical network capacities. Through the implementation of model framework conditions, alternatives can be evaluated. Results are based on a combination of methods flanked by experimentation and empirical research.

The group “Design” works on visualization technologies for product applications, processes and user interfaces.

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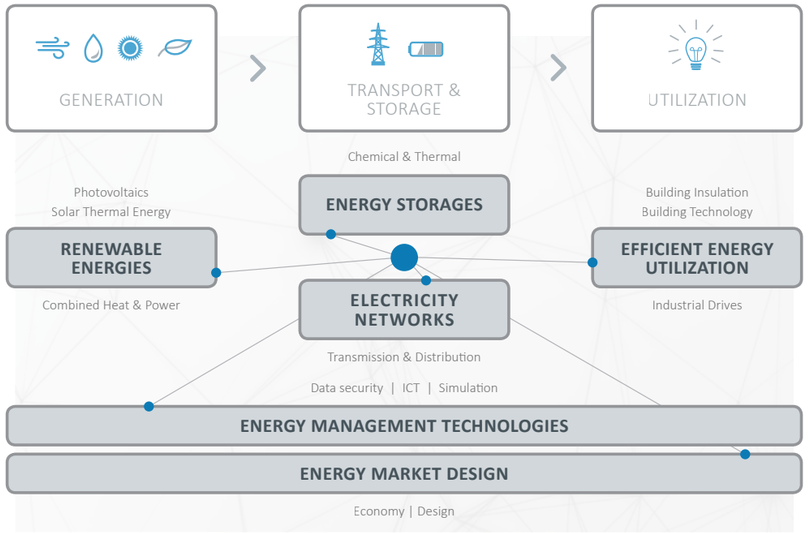
Collective research on the energy chain

The Energie Campus Nürnberg (EnCN) is a **research alliance** that develops new technologies for integrated energy systems. Six research institutes within the metropolitan region of Nuremberg cooperate as an **independent research network** and operate as an **interdisciplinary think tank**. The EnCN works together with companies on research projects to find safe, cost-effective, climate-friendly, socially-acceptable and sustainable energy supply solutions based on renewables. Through this, a tangible contribution to energy revolution objectives is achieved.



Our **research alliance** unites competencies along the entire energy supply chain, which includes six areas of concentration. In addition to the classical natural and engineering science fields, the EnCN provides economic know-how and design expertise.

The main advantage of the EnCN is the combination of various disciplines and institutions under one roof. Specific to the request of the respective developmental work, flexible teams from different areas of concentration and/or research institutes can be formed to provide the best possible results for the client.

About the EnCN
Interdisciplinary Cutting-Edge Research

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We establish the connection

Specific to the task, the EnCN offers a principal contact that can connect you to the right person within the network. A wide variety of collaboration arrangements is possible:

Bilateral R&D-Projects – Customized cooperation with the EnCN

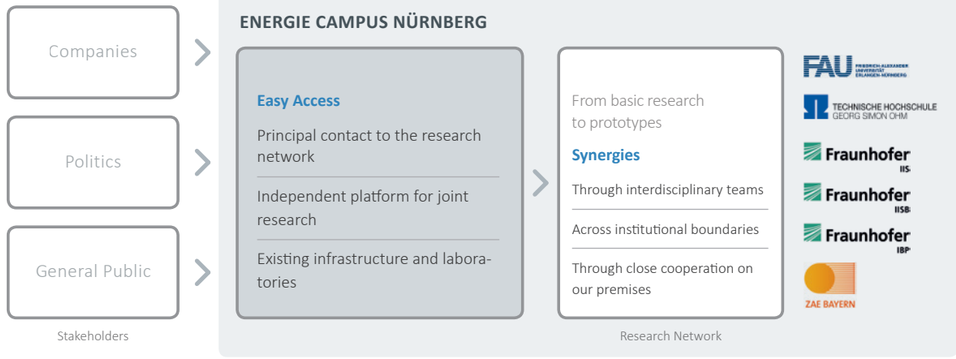
Joint Projects – with & without funding – EnCN as a partner in cooperation, supports with conceptual design, submission of research proposals, coordination and implementation of the research.

Test Series – Accelerated lifetime testing, long-term measurements or special test cycles

Individual measurements – Special measurement techniques and customized measurement set-ups.

Doctorate, Master & Bachelor theses – Arrangement & supervision of scientific studies

Events – Knowledge sharing of the current state of energy research



In focus: research and development

We have chosen a comprehensive approach for our research and development to better display the complexity of energy systems in our work. Our approach is integrated, interdisciplinary, spans across institutional boundaries, networked, independent and flexible.

This work method allows the EnCN, to offer a wide variety of options. We provide solutions from the complete line of research – from strategic basic research to applied development of a finished product.

Highlights

Renewable Energies

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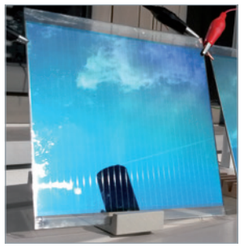
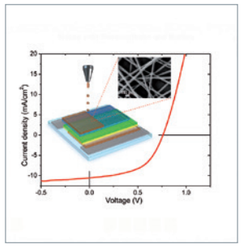


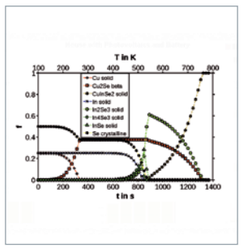
Printed organic solar modules

Ultra-precise laser patterning with femtosecond pulses allows a reduction of the inactive interconnection area of printed organic solar modules down to ~100 µm. Thus, our solar modules exhibit a worldwide unique geometric fill factor of 98.5% and are perfectly suitable for building-integrated photovoltaics due to their superior aesthetics.



Ink-jet printing of silver nanowires

Digital printing of silver nanowires is demonstrated for the first time by the solar fab of the future. Fully ink-jet printed organic solar cells show the potential of such semitransparent electrodes. With efficiencies up to 4.3%, these cells hold the record in this field of application.



Computer simulation CIS layer and phase formation

This is an example for the calculated phase and layer formation process in the manufacture of CuInSe2 solar cell absorber. The locally formed phases are calculated by means of a finite-volume computer simulation of the underlying material diffusion processes and the associated chemical reactions. A cellular automaton determines grain boundaries that separate different phases.

Large-area printed mirrors

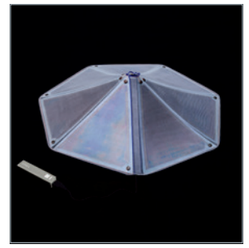
Large-area dielectric mirrors are manufactured and combined with semitransparent solar modules. This approach enables an efficiency improvement without reducing the transparency. Moreover, the color of the modules can be modified, which opens up additional design possibilities for building-integration. Both the mirrors as well as the solar modules can be produced by cost-effective printing processes.

Solar images

All layers of organic photovoltaic cells can be deposited by ink-jet printing in arbitrary shapes and at any desired layer thickness. It is now possible to manufacture “multi-colored” solar images with this technique. This is a crucial step towards the digital printing of solar cells.

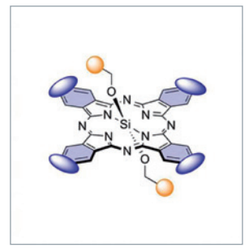
Integration of organic photovoltaics into textiles

In the field of textile integration, organic photovoltaic displays its full potential regarding flexibility, low weight, and outstanding design freedom. Integration into a jacket or a backpack provides a portable energy source, e.g. for charging a cell phone.



Water-soluble organic semiconductors

Novel organic semiconductors offer enhanced light absorption and more efficient charge carrier transport to increase the efficiency of organic solar cells. Our water soluble organic semiconductors can be easily integrated in solar cells in an environmentally friendly way.



Roll-to-roll printing of flexible solar modules

Roll-to-roll printing enables the cost-effective and environmentally friendly manufacture of solar modules based on various technologies. Our printing line was specifically developed for the production of small series.

Highlights

Energy Storage

Storage by liquid organic hydrogen carriers

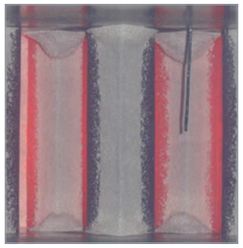
Liquid organic hydrogen carriers (LOHC) offer a safe and simple method to store energy in the form of hydrogen over long periods of time. Hydrogen is chemically bound to a carrier molecule by a catalytic reaction. The resulting hydrogen-rich form of the LOHC can be stored and transported under ambient conditions. The hydrogen can be catalytically released on demand. The LOHC-technology is especially inexpensive for large storage volumes. For demonstration purposes, a small-scale hydrogen-storage module was built.

Reactors and process design for SNG production

The generation of synthetic natural gas (SNG) from synthesis gas offers an approach for large-scale and long-term storage of renewable energy. Maximum benefit is generated if reactors and processes for SNG-production can be operated dynamically and flexible with regard to reactants. We contribute by developing and testing innovative reactor concepts and process chains for decentralized applications.

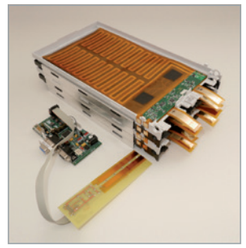
High-temperature heat reservoir for LOHC systems

A high-temperature heat reservoir has been developed for hydrogen release in LOHC systems. This reservoir utilizes the oxidation of iron with water for thermal release. This reaction releases addition hydrogen that can for example, be used in fuel cells. With this reservoir, the existing heat in the LOHC process can be reused. In this way, the efficiency of the hydrogen storage system is improved. The heat reservoir can reach temperatures up to 450 °C.



$CaO-CaCO_3$ high temperature heat storage for peak load shaving

This high temperature heat storage based on a CaO-CaCO3 cycle operates isothermally at a temperature level between 800 - 900 °C. It offers high storage densities and is applicable e.g. for the flexibilization of steam production in existing thermal power plants.



Battery control with decentralized battery electronics

With this concept, every cell contains monitoring electronics. Over a capacity-coupled bus, the cell voltages are transmitted to a central battery management system. Thereby the module construction is more flexible and adaptable. The bonding expenditure is greatly reduced.

New electric vehicle battery module with high energy density and cost-optimized monitoring electronics

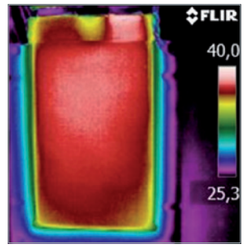
As part of an international project, a completely redundant battery system with management algorithms for an electric vehicle was developed. The battery module was designed together with Dräxlmaier (Germany), Panasonic (Japan) and IFEVS (Italy). The system is deployed in an electric vehicle prototype that was presented at the Parco Valentino Car Show in Torino.

Construction of a storage station

A storage station was constructed and demonstrated utilizing three sub-storage systems with a capacity of 20kWh each. Each sub-storage system has a permanent power of 100kW with a 320 A charging and discharging current. The monitoring electronics measure the individual cell voltage with an accuracy of 1.2 mV. Through the redundant design, the storage system reaches a 24/7 operational availability, making it suitable for grid applications.

FoxBMS – free, open, flexible battery-management-system

A new Battery Management System (BMS) was implemented. In order to ensure maximum flexibility and speed for future developments and requirement changes, the hardware as well as the software were developed completely modular. The availability of the developed code as open source supports collaboration.



Shorter simulation times for thermal-electrical simulations of battery systems

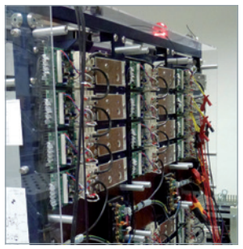
An improved simulation flow was created as part of the developmental process for the thermal design of battery systems based on lithium-ion cells. The simulation time for coupled thermal-electrical systems was reduced by a factor of 1600, which enables the complete simulation of a battery module or even battery packs.

Highlights

Electricity Networks

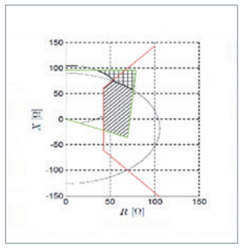
Innovative design concept for semiconductor power modules

A novel power module concept with special packaging for Modular Multilevel Converters has been developed and qualified. Due to this, it is possible to exploit the semiconductor's full operational performance and e.g. to increase the used components' overload capability. A notable challenge lays in the high lifetime requirements for applications in the energy sector with operating lifetime of more than 40 years.



Grid access of multiple energy storage technology

Modular Multilevel Converters are adapted for the grid access of volatile energy in-feeds and energy storages of various technologies. This approach enables a system operation method which follows the load characteristic. Such an advanced grid structure with energy storage units in the range of kW has been installed in our power electronic lab and its extensive functionality could be confirmed by real hardware tests. Moreover a flexible charging management of the energy storage units could be realized and verified.



High grid loading with high grid security

In different fields, new adaptive protection algorithms as well as methods of automated protection coordination have been developed. These approaches allow to increase the grid loading during a high degree of grid security. By the way, the transient grid stability can be increased by application of the developed algorithms, as grid faults will be detected and cleared selectively and fast.

SWARM – storage with amply redundant megawatt

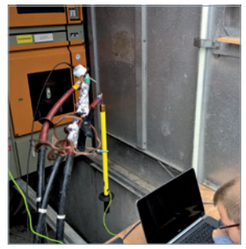
For the companies of N-ERGIE and Caterva, the interaction between energy systems and storage systems with regards to the fixed performance in distribution grids and frequency stability in transmission grids was investigated. Through network calculations, the interaction between storage and the power grid could be simulated and verified by measurements. It was examined to what extent the storage system influences the future scale of grid expansion in distribution and transmission lines.

Innovative measurement vehicle for power cable diagnostics in distribution grids

In cooperation with a major German grid operator and an internationally active diagnostics company, an innovative and unique measurement and test system with high-resolution hard- and software components for the acquisition of diagnostic parameters of medium voltage power cables is developed. The field measurements can indicate the ageing condition of specific cable lines and can contribute to the safety of grid operation.

First spatially-resolved evaluation data of power cables

In cooperation with a leading company in power cable diagnostics, a new non-destructive method for spatially-resolved diagnosis of power cable systems has been developed. The meanwhile patented method enables for the first time a spatially-resolved illustration of the dielectric characteristics, which are of major importance for a reliable grid operation. As a result, single cable segments can be identified before a cable failure occurs.



Hybrid energy storage

The hybrid energy storage is a demonstrator for the grid integration of renewable energy systems and energy storages. It is used to investigate the parallel mains operation and isolated operation for combinations of different storage technologies and renewable energies. Furthermore, the interaction of different storage technologies are analyzed and optimized control algorithms are derived.

Antifuse – bypassing defective battery cells

A new component that bypasses defective power electronics elements was developed and a range of patent applications were submitted. This innovative component can generate a low-resistance short circuit within milliseconds, thereby creating a current path around the defective element. This is important for serial circuits such as lithium-ion battery systems or HVDC-facilities, where an antifuse can prevent a total system failure.

Highly efficient inductive charging systems for electric vehicles

The compactness of the vehicle side coils is outstanding, coupled with a similarly high transmission efficiency of up to 97 %. For local communication between the charging point and the car, a low data rate and robust communication channel in the energy transmission system (with a maximum output of 3.5kW) was successfully integrated. Therefore, the existing transmission coils can be used and radio modules are not necessary. With near-field communication, important status updates of the charging process can be transmitted.

Highlights

Energy Management Technologies

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OGEMA 2.0 is an open source framework for energy management systems

The java-based framework is open source and can be used with different hardware. With OGEMA 2.0, individual applications can be created for the energy consumption management based on e.g. the interaction with dynamic electricity prices or the control of environmental parameters, such as temperature and humidity. OGEMA 2.0 provides an app-based development environment and an integrated security concept.

Power measurement system for large consumers

A robust power measurement system for electric consumers in an industrial environment was developed together with Rauschert GmbH and is ready for commercialization and VDE-certified. The measurement system uses sensors positioned circularly around the conductor. This approach achieves high temporal resolution, better surge current capability and a high dynamic range. In addition to the current measurement a sensing mandrel is used to measure the voltage. This system received the recognition award – Energy Efficiency Award 2016 from dena.

Wireless IoT-based energy management technology

MIOTY enables a cost-effective deployment of sensors in areas covering several kilometers. With more than 1 million sensors and an operation capacity of up to 10 years, MIOTY is the starting point for new applications and business models for especially the area energy management but also the Industry 4.0. MIOTY has a flexible design; special evaluation kits are available for initial installations in new applications.

Optimal planning of gas networks

Efficient transportation of natural gas through pipeline systems is and will be increasingly important within the near future. In particular, the integration of market mechanisms and the coupling of energy carriers in the context of Power2Gas technologies pose new questions of great interest. Thanks to new mathematical and algorithmic developments of members of the EnCN it is now possible to find optimal solutions of planning and control problems for realistic networks on a national scale.

Simulation of smart energy systems

With the i7-AnyEnergy simulation framework, connected smart energy systems with many conventional and renewable energy conversion units can be quickly modeled and simulated. This includes consumer, weather, and control models as well as energy and cost flows. Based on the basic components, house models can be created and combined with a shared weather model and a communication network. This allows, for example, the investigation of operating strategies of decentralized batteries.

Energy system analysis

In co-operation with the Bavarian Ministry for Economics and numerous companies from the energy sector, we analyzed and evaluated possible courses of action in Bavaria concerning energy balances, the energy input, and environmental issues with the help of simulation and optimization techniques. To this end, the most important components of the energy system have been simulated with respect to technical and economical restrictions. Furthermore, the interaction of highly fluctuating renewable energy sources with power plants and storage devices has been integrated in the model. The work is continued within the project KOSiNeK that is funded by the BMWi.

SWARM - simulation of distributed storage systems

In co-operation with N-ERGIE AG and Caterva GmbH, a virtual electrical energy storage was installed in the SWARM project. For this virtual storage, composed of small electrical energy storages placed in residential households, we developed a simulation model which determines the technical effects of the storages on the grid and identifies the economic benefits for the private households involved and for the entire electrical energy system. In addition, innovative control algorithms could be tested and evaluated for both the single installed as well as the virtual storage.

Showcase electromobility “e-NUE“

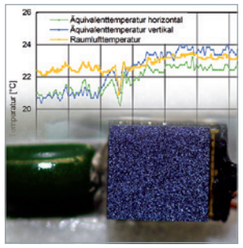
The project “e-NUE” deals with electric mobility and the impacts upon the electrical energy system. For this purpose, a simulation framework has been developed to identify relevant effects, like energy demand, charging times, or CO_2-emissions. This tool can be used to analyze, evaluate, and optimize technical and economic results for the electrification of commercial vehicle fleets.

Highlights

Efficient Energy Utilization

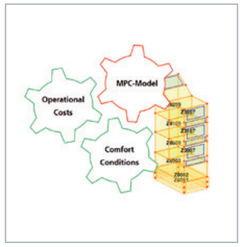
Market launch of a new zeolite-adsorption chiller

In a close collaboration with the SorTech AG we were able to launch a new zeolite based adsorption chiller showing an enhanced performance. The innovation is the development of an optimized connection between a high-performance adsorbent layer and the heat exchanger surface. This has been achieved by direct crystallization of the zeolite onto the heat exchanger surface leading to a mechanically stable intergrowth of the two layers.



Comfort sensor for room automation

To measure thermal comfort, especially in terms of radiant temperature and air speed, an equivalent temperature sensor was developed and linked to the wireless communications protocols EnOcean and ZigBee. In the future this development offers the possibility of using „thermal comfort“ directly as a control variable in building automation and control systems.



Model-based and data-driven control optimization for technical building services

Optimized control strategies of technical building systems provide a high potential for energy savings. Therefore, different approaches based on simplified linearized physical models or full simulation models are used. To describe the influence of the users and adapt control strategies to them, statistic models with included uncertainties can be used.

Semantic data model for fault detection in building automation systems

Algorithms using building operation data can detect and identify faulty settings in technical building systems. Therefore, a comprehensive knowledge about the technical systems, their operation and data points is necessary. Using semantic information models to describe this knowledge allows an automatic linking of fault detection algorithms and measured data. In the developed information model additionally control logic and its connection to technical systems is described.

Herzo base energy storage homes: a flexible energy and building concept for the future

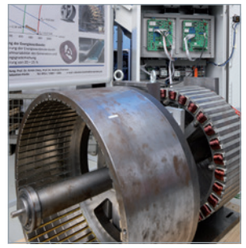
A row-house complex containing eight units was constructed as part of a pilot project. The buildings incorporate modern highly-thermal insulating massive construction materials with integrated insulation, as well as new management concepts for geothermal heat pumps with electrical and thermal storage in combination with PV installations.

Emulation test bench for thermal energy producers and storage systems

The emulation test bench allows the testing of modern thermal generating units, e.g. heat pumps and mini CHP-Units. The coupling of the test bench with the thermal building simulation program TRNSYS allows tests that are carried out under almost real conditions. In addition to increase the energy efficiency of the units, the development of new controls strategies for the components is the focus of this research.

Permanent magnet synchronous machine as a generator for small hydropower plants

Currently, induction machines with a gear-box are used in most small hydropower plants. The unfavorable efficiency of induction machines during partial load conditions has proved to be a disadvantage during low water periods. The newly developed high-pole permanent magnet synchronous generator is very suitable for these operational conditions and does not require a gear-box or slip rings and brushes. By using a frequency converter the rotational speed of the machine can be varied over a wide range, which results in overall efficiency gains.

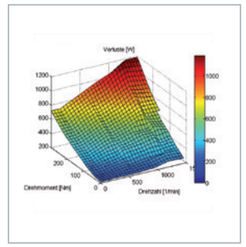


Efficiency increase of conveyor and lifting systems

The efficiency of conveyor and lifting systems, such as elevators or storage and retrieval systems, can be drastically increased through the use of energy recovery units. When lowering a weight, its potential energy is transformed back to electrical energy and fed into the power grid. In the case of storage and retrieval systems, regenerative breaking for horizontal motion could be implemented as well. Much potential also lies in optimal system management when employing multiple operating panels (e.g. in an elevator). A double-digit percentage gain in efficiency could be demonstrated by using an energy recovery unit and an optimized control algorithm.

Power dissipation maps accelerate the simulation of electrical drives

Research on energy loss mechanisms in electrical machines and drives significantly improves the understanding and the modeling of these losses. Incorporating recent findings, simulations of electrical drive systems were accelerated by a factor of 1000, by using power dissipation maps. This enables a precise energetic analysis and optimization, even for complex electric drive systems, over extended operating cycles.



Highlights

Energy Market Design

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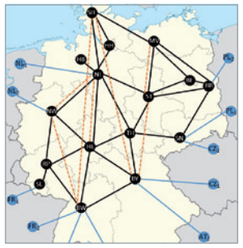


Investment incentives and business models in the power market

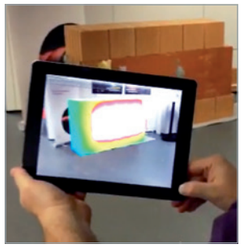
The recent EnCN expert report “Decentralization and Cellular Optimization” uses electricity market models to investigate the optimal interplay of grid expansion and decentralized solutions in power supply. The report analyzes moderate and more complex adaptations of the electricity market design and shows possible efficiency gains from a long-term perspective. Particular aspects analyzed include (among others) the optimal feed-in management for renewables, different locational incentives for renewable production, the use of storage facilities, as well as locational prices.

Smart grid business model

In cooperation with the project “Smart Grid Solar“ the EnCN developed an integrated grid and market model that is capable to analyze the interaction of electrical grid management, electricity supply, storage and consumption at the level of distribution networks. The model allows to investigate the scope for smart grid business models under different regulatory frameworks and opens up the opportunity to evaluate policy proposals for the future organization of smart energy markets.

Investment decision in small storage systems

As part of the acceptance and consumer research within EnCN, the group conducted a large panel survey within the project SWARM, where household storage devices were installed in private homes and linked together in order to also offer system services. The study evaluated the attractiveness of this type of household storage device for different customer groups and identified conditions under which investment is more likely. It was shown that in particular older customers who support the energy transition have a high propensity to invest as customers that focus on supply security.



Augmented reality in the visualization of heat dissipation

With the help of augmented reality displays (AR) it is possible to map temperature data onto reconstructed 3D data from either 3D scans or construction data. This helps understanding heat dissipation directly in the operating environment when viewing critical parts of buildings, or other objects under investigation. This new approach is especially helpful in building renovation projects to identify spots with increased thermal conduction and to develop more efficient solutions.

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Welcome

The central office of the Energie Campus Nürnberg is your first contact for your needs

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