E.ON Energy Research Center

Research & News

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News on Research & Education at E.ON Energy Research Center of RWTH Aachen University

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Topics of this issue

Editorial

Dear Readers,

Research & News regularly reports on the many different research activities under way at E.ON ERC, and on projects that are both interesting and important. The new large-scale battery storage system is certainly a major highlight and flagship project in this context. After all, the German energy transition to largely renewable power generation is inconceivable without storage. What is needed is both large units for long-term storage and smaller units at the local and regional level. With the new large-scale battery storage system, we are taking steps toward a decentralized storage technology that is independent of local geographic circumstances. In addition, it also offers high dynamic control performance and the potential to be economically succesful managing properly the charging an discharging cycles in the electricity market.

Happy reading!
Rik W. De Doncker

E.ON ERC I Energy storage

Aachen to host world's unique large-scale battery storage system

Institutes at E.ON ERC responsible for concept, operation, system integration and academic and scientific support

Germany's energy transition needs storage. Alongside storage facilities to help compensate for long-term fluctuations in generation and demand over the course of the year, buffer storage is also needed to help compensate for short- and medium-term dips in production or peaks in demand. The world's first large-scale modular battery storage system in the five-megawatt power class is currently being built in Aachen for just these short- and medium-term uses. The project, entitled M5BAT (**M**odular **M**ulti-**M**egawatt **M**ulti-Technology **M**edium-Voltage **Ba**ttery Storage), encompasses 12.5 million euros in investment volume. The German Federal Ministry of Economics and Energy is providing about half of the total, with 6.5 million euros in funding as part of its Energy Storage Funding Initiative.

The partners in academia, the research sector, and the business sector that are involved in this project are E.ON ERC at RWTH Aachen University, including the PGS and EBC institutes, the RWTH Institute

Source: E.ON SE

The large-scale battery storage system is being built in an existing building on Aachen's Hüttenstrasse.

of Power Systems and Power Economics (IAEW), the energy provider E.ON SE, battery manufacturers Exide Technologies and Beta-Motion, and inverter manufacturer SMA. The partners will be working together over four years to optimize the structure, construction, and operation of these kinds of large-scale battery storage systems.

What makes M5BAT distinctive, aside from its size, is the modular structure of the storage system. Different battery technologies are being combined across five banks. Two lithium-ion banks will serve above all to provide short-term compensation for up to 0.6 hours. These batteries feature high output and accordingly fast charge/discharge cycles, but are – still – more expensive than lead-acid batteries, which will account for two other banks. Assuming a full charge, these batteries will discharge the rated output over a period of about one hour. The fifth bank of batteries will consist of sodium nickel chloride high-temperature batteries that serve to provide energy for about two hours. Overall, the large-scale battery storage system, located on Aachen's Hüttenstrasse, is designed to ensure that even if one bank fails, a reliable output of five megawatts can still be fed into the medium-voltage grid via the neighboring substation.

Compared with conventional storage methods, battery storage systems have a number of advantages. Unlike pumped-storage hydroelectric plants or compressed-air energy storage, location decisions for batteries are completely independent of geographic circumstances, with economic and technical considerations being the deciding factors instead. Long periods of preliminary planning are not necessary, in part because it is relatively easy to accommodate environmental protection requirements in choosing a site.

M5BAT – goals

- Development of a design manual for battery storage plants in a medium-voltage grid (cost-optimized structure, security technology, control technology, operating costs)
- Preparation of guidelines for pre-qualification for various market segments
- Conceptual development for cost-effective operation in a medium-voltage grid
- Optimization of system controls (operation and battery management)
- Development of controls for inverters in battery storage plants
- Determination of standard load profiles for various market segments
- Establishment of a requirements catalog for the further development of battery technologies
- Development of optimized battery cells for certain load profiles
- Studies of reliability, lifespan, and efficiency

Thanks to the modular structure with its multiple battery banks, the planned academic research to be performed as part of this project goes far beyond the field of technical layout and functionality of various storage techniques. The project will primarily be exploring ways to integrate electricity generated through renewables more easily into the complex supply system, but it will also look at whether, and if so how, the different banks and overall system are suitable for providing or delivering primary and secondary reserve power, reactive power compensation, and for use of electrical price differences in electricity trading.

Within this project, energy provider E.ON SE is handling the renovation of the existing building and, with support from the RWTH institute IAEW, the marketing of the electrical energy for various applications in the energy market. Operation of the system, system integration, and scientific support and supervision will be provided by the institutes at E.ON ERC. The above-mentioned manufacturers will supply the various components. In principle, additional innovative battery technologies can also be put to the test in the future. Construction work is scheduled to start this fall, with the large-scale battery storage system going into operation in 2015.

E.ON ERC I Forschungscampus Future Electrical Networks

First main phase: four projects with ten million euros in funding volume applied for

The Forschungscampus (Research Campus) Future Electrical Networks (FEN – see *Research & News Nr. 3/2013 und Nr. 4/2013*) is taking concrete form. Work is slated to get under way in the first main phase on the RWTH campus right away. A report on the progress that has been made and the applications submitted for specific individual projects – both of which are among the preconditions for further funding of the FEN by the German federal research ministry – were edited and published in late March. The four project applications were developed by RWTH with close cooperation of industry partners, under the leadership of Professor Rik W. De Doncker and the management of the PGS institute at the E.ON ERC. Before that, the planned research topics were presented at workshops with industry partners and discussed in detail. The specific projects are:

- Modeling, planning, conceptualization and evaluation of networks of the future
- System and network technology
- Control, operational management, automation

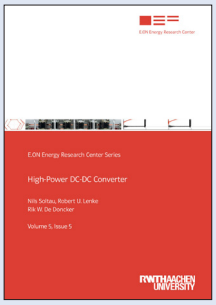
- Layout, development and operation of Aachen MVDC research grid.

For the first main phase in the activities of the research campus FEN, which will run for five years, ten million euros in funding has been applied for. Two additional five-year main phases with the same level of funding may follow, assuming that the first projects have gone successfully and the need to continue the research is made clear, for example through new project applications.

The objective of FEN is to improve electrical networks for an energy supply with a rapidly rising percentage of energy from volatile renewable sources. In their current form, and as this development takes shape, electrical grids seem more like the choke point in the energy transition.

FEN focuses on studying DC grids with high flexibility and lower losses. The flagship project for the first main phase is a medium-voltage DC grid being constructed on the RWTH campus for research purposes. Further experimental work involving this grid is to be performed in the two subsequent main phases.

"High-power DC-DC converter" final report published



As part of the project, a 5-megawatt DC-to-DC converter for medium-voltage applications was developed at the PGS institute, using the dual active bridge principle. DC-to-DC converters are an important basic component of future DC networks. The report was published at E.ON ERC.

FEN represents a new form of intensive long-term cooperation between academia and industry. Joint fundamental research is receiving direct support through funding from the German federal research ministry. In addition, the close physical proximity on campus will foster mutual understanding between the partners from industry and the academic community and ensure that the results of fundamental research can be applied faster. In-depth cooperation across additional funded projects or direct contract research for development of prototypes or products is a stated aim between industry and the university.

During the one-year preliminary phase for the research campus, the cooperative concept was developed jointly with the industry partners. A detailed cooperation contract was put in place and a managing company called Flexible Elektrische Netze FEN GmbH was founded. This company acts as the central coordination body for businesses and the university. It will be financed through contributions from the companies and licensing revenues based on marketing of industrial property rights that arise in the course of the project.

FCN I Alternative vehicle drives

Conventional engines continue to dominate the market

Prospects for alternative drives trains improve with larger ranges, lower maintenance costs, and better environmental protection

Better fuel economy, lower purchase prices and emissions, and larger ranges are the main things consumers require from vehicles with alternative drives, according to the main results of a survey conducted by the FCN institute at E.ON ERC as part of a recent study. The survey focused on how consumers can be motivated to purchase a vehicle with an alternative drive. All 711 respondents from Germany had purchased a vehicle in the previous year or planned to buy a new one within a year.

There were seven drive types listed in the survey: biofuel, natural gas, hydrogen/fuel cell, hybrid, plug-in hybrid, full electric, and conventional gasoline or diesel combustion engine. According to the study, the factors with the strongest influence on the choice of vehicle type are the purchase price, costs of fuel, and CO_2 emissions. Younger respondents and users who drive primarily in urban settings prefer hybrid or electric vehicles, with the decision in favor of pure electric drives being affected mainly by driving range and battery charging times.

Source: Volkswagen AG

Among alternative drives, hybrid and natural gas engines (image) currently have the brightest prospects on the market.

Low maintenance costs increase acceptance of higher purchase prices. For example, the car buyers surveyed are willing to pay a price that is between 530 and 1,070 euros higher, depending on vehicle class, if that means in return that the fuel costs are one euro lower for every 100 kilometers. For each percent of vehicle-specific CO_2 emission reduced, purchase prices of between 20 and 90 euros

more are accepted. Survey respondents would also accept rising prices in exchange for extended ranges, approving between 16 and 33 euros more for each additional kilometer driven in vehicles with all-electric drives and anywhere from eight to 17 euros in the case of the other kinds of alternative drives.

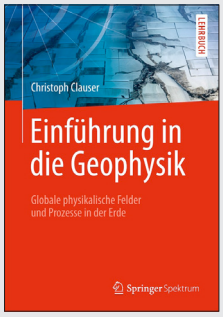
Targeted government support can also have a significant impact on purchasing decisions. If a tax exemption is granted over the vehicle's entire lifespan, sales prices can be from 2,330 to 4,700 euros higher than those for vehicles with conventional drive systems. Even "soft" factors such as free parking or permission to use bus-only lanes boost the prices respondents find acceptable by 1,620 to 3,280 euros.

Regardless of the nature and extent of the improvements in the characteristics of vehicles with alternative drives, conventional engines will continue to rule the vehicle market for a long time to come. Among vehicles with alternative drives, respondents believe natural gas and hybrid drives have the brightest prospects. In the case of purely electric vehicles, the survey results show that rising success on the market cannot be expected until a single battery charge is enough to drive about 750 kilometers.

The survey results were published under the title "Consumer preferences for alternative fuel vehicles: A discrete choice analysis." To request the article and additional materials on this topic free of charge, please e-mail *newsletter@eonerc.rwth-aachen.de*.

New geophysics textbook

A new textbook titled "Einführung in die Geophysik" (Introduction to Geophysics) has been published, the first of its kind to be published in German since 1990. The



book's author is Professor Christoph Clauser, head of the institute GGE at E.ON ERC. It summarizes the current status of knowledge on global physical fields and processes within and outside the earth in a modern form.

In the book, Clauser introduces beginners to geophysics at an intermediate level. Students of geophysics, earth sciences, environmental studies, physics, and geoecology will gain a fundamental understanding of the physical forces, fields and processes within and outside the earth. Mathematical derivations are explained in detail where necessary. Exercises allow students to check what they have learned.

All of the book's chapters are prefaced by a brief historical section that explains how the discipline dealt with in that chapter has developed up until the very recent past. Biographical information on selected scientists shows the outward and personal conditions under which groundbreaking results have been produced.

Einführung in die Geophysik has been published by Springer Spektrum and is available from the publisher for 59.99 euros in hardcover or 46.99 euros as an e-book. For more information, please visit *www.springer.com* and see the Geowissenschaften/Angewandte Geowissenschaft (Earth Sciences/Applied Earth Science) section or click ***here***.

ACS I Institute gains competencies and capacity

Welcome support for EU projects

E.ON ERC is continuing to grow. In the last few weeks, for example, the ACS institute headed by Professor Antonello Monti integrated one associate professor (akademischer Oberrat), one research associate, one software developer, and two apprentices from the former Chair for Operating Systems at RWTH Aachen in order to significantly expand the competencies and capacity of the "ICT for Energy" research group. By expanding in this way, the institute will benefit in particular with regard to the further development of simulation environments for electrical networks on the path toward smart grids. In concrete terms, the new colleagues have been working as part of the German Federal Ministry of Education and Research (BMBF) project FAST (Dynamic Topologies in Extremely Scalable Environments) since the beginning of the year.

The new staff will also be helpful in five EU projects that are running simultaneously, in which ACS is involved in cooperation with international European partners from the academic and research sectors and industry. As part of the FINESCE research project (*Research & News 3/2013*), for example, ACS is working as part of the EU's ***FI-PPP*** program to simulate intelligent electrical grids for selected cities and regions. For COOPERATE (*Research & News 2/2013*), the institute is working together with six other partners from research and academia and the business sector to develop "energy-positive neighborhoods" in order to coordinate various types of renewable power generation and energy use effectively and efficiently at the local level. ***IDE4L*** (Ideal Grid for All) focuses on an architecture for automation of distribution networks, while the GEYSER project is developing an energy-optimized data center as an important element of smart grids, and the ***MERLIN*** project aims to optimize energy management in railway systems as part of overarching networks.

GGE I International cooperation on geothermal energy

German-Canadian working group pursues bilateral research project

The international approach taken by E.ON ERC is clearly apparent in various ways, including the center's many cooperative arrangements within the scope of the International Energy Cooperation Program (*IECP*). On the bilateral level, the center's philosophy is evident in its membership in the Canadian-German U15/U20 initiative, in which 15 leading Canadian universities and 20 German ones have joined forces to generate synergetic effects through international cooperation. The goal is to map out joint research topics and then, as the next step, identify and implement specific research projects that merit support in two fields: "smart grids for the future" and "innovative geothermal field systems." To this end, two working groups for the respective research topics have been founded under the leadership of the University of Alberta, Canada, and E.ON ERC at RWTH Aachen University in Germany.

A first joint workshop in the geothermal energy working group was held in Edmonton, Canada, on December 6, 2013, during which four areas of focus for research activities were identified. After that, the researchers met in early March 2014 at E.ON ERC at the invitation of the GGE institute in order to set out concrete details for their work and identify possible projects and financing options. Over the course of the discussion, it became clear that renewable geothermal energy is still considered more of a niche in both countries. The researchers concluded that the only way to change this will be through projects with global relevance. Against this background, long-term use of geothermal reservoirs was identified as a particularly important topic. Based on research projects that are currently under way, but whose importance lies more at the local level, the researchers plan, finally, to develop an overarching project on the topic of creating and maintaining geothermal reservoirs that is of interest to the national research funding sectors in both countries.

FCN I Colloquium

Dr. ir. Erik Delarue of Katholieke Universiteit Leuven gave a presentation titled "**Modeling electricity generation systems: on integration of renewables and CO_2 abatement**" in mid-March as part of the FCN Colloquium series. His talk focused on how CO_2 prices affect power generation structures and the development of the relevant emissions as well as the effects of increasingly renewable generation on CO_2 prices. Ultimately, Delarue said, use of power plants will be affected to a large extent by the price of carbon allowances. Low prices for allowances, which are practically an automatic product of increases in power generation from renewable sources, tend to favor the use of coal and lead to increases in CO_2 emissions in other economic sectors as well. Eco-friendlier power generation with efficient natural gas power plants does not become economically attractive until the costs of allowances rise. The scope of reduced emissions also depends significantly on the prices of raw materials and on grid loads. CO_2 emissions decrease to a remarkable degree when both demand for electricity and raw material prices are moderate. This advantage shrinks, however, as the prices of natural gas and coal rise and power consumption grows.

Professor Reinhard Madlener of FCN and Dr. Delarue plan to pursue further cooperation and are currently preparing their first joint research project.

Events/Dates at E.ON ERC

April 15, 2014, 4.30 p.m.	**Colloquium: The Impact of Distributed Generation on Utility Business Models: How Imminent, How Serious?** Dr. Fereidoon P. Sioshansi, President of Menlo Energy Economics, California, USA
Information/e-mail:	*colloquium@eonerc.rwth-aachen.de*

E.ON ERC I E.ON Energy Research Center, RWTH Aachen University,
Prof. Dr. ir. Dr. h. c. Rik W. De Doncker

ACS I Automation of Complex Power Systems, Prof. Antonello Monti, Ph. D.

EBC I Energy Efficient Buildings and Indoor Climate, Prof. Dr.-Ing. Dirk Müller

FCN I Future Energy Consumer Needs and Behavior,
Prof. Dr. rer. soc. oec. Reinhard Madlener

GGE I Applied Geophysics and Geothermal Energy, Prof. Dr. rer. nat. Christoph Clauser

PGS I Power Generation and Storage Systems, Prof. Dr. ir. Dr. h. c. Rik W. De Doncker

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