Annual Report 2016

Flexible Electrical Networks (FEN) Research Campus
FEN GmbH
Campus-Boulevard 79
52074 Aachen
Germany

+49 241 80 22471
info@FENaachen.net
www.FENaachen.net

ISSN 2364-9720
Dear readers,

Whoever conducts research in the field of electrical grids, takes responsibility for our future energy supply. We took on this responsibility once again in 2016 in order to enable a sustainable, reliable and affordable energy supply system.

In the last year, we have further focused our core competences in several research projects and made considerable progress. In addition to the BMBF funded FEN Research Campus projects, we received approval for two new research projects: “RESERVE” and “FISMEP”, which are funded by the European Commission and the German Federal Ministry for Economic Affairs and Energy (BMWi), respectively. Another positive development we would like to mention, is our move to a larger office space, due the growing number of research partners who are active in our Flexible Electrical Networks (FEN) Research Campus.

We would like to express our gratitude to those who have actively contributed to these positive developments: in particular our RWTH Aachen University partners, industrial partners and sponsors.

In 2016, we performed the groundwork for further growth and cooperation within FEN Research Campus. We are looking forward to continuing our positive development throughout the coming year and taking up further exciting challenges.

Sincerely yours,

Prof. Antonello Monti, Ph.D.       Prof. Dr. ir. Dr. h. c. Rik W. De Doncker       Prof. Dr.-Ing. Albert Moser
Co-Director FEN Research Campus             Director FEN Research Campus                                        Co-Director FEN Research Campus
Chairman of LV Consortium                        Chairman of MV Consortium                                   Chairman of HV Consortium

Photo (from left to right):
Prof. Antonello Monti, Ph.D., Prof. Dr. ir. Dr. h. c. Rik W. De Doncker, Prof. Dr.-Ing. Albert Moser
A sustainable, reliable and affordable energy supply in the future – this is the vision of Flexible Electrical Networks (FEN) Research Campus.

This vision arose from the many changes that occurred in the electrical supply system in recent years. The existing three-phase alternating current (AC) electrical supply system was designed for a top-down transmission and distribution of electrical energy produced by a few large central power stations. While this was an appropriate solution for the safety and protection requirements and available technologies from the past, the situation has now changed fundamentally. Sustainable energy sources and new electronic power conversion technologies have become technically and economically feasible and a constraint to AC technology is no longer a must, but rather an obstacle. Many small-scale decentralized energy sources like PV solar systems on the roofs of homes and buildings, produce energy, which is distributed over the whole country. This means that the formerly exclusive consumer now becomes a producer, or so-called prosumer. At the same time, large-scale, gigawatt power generators, like offshore wind farms, sometimes have to be connected over long distances. Transmission, distribution and storage of electricity need to be more efficient and flexible, so fluctuating and decentralized production can be handled more easily and economically.

Consequently, a more decentralized power production of electrical energy has a strong impact on the required characteristics of future power grid. Our vision is that the future grid must be more flexible and that it will be ideally implemented by intelligent power electronic conversion systems, being the successor of former 50/60Hz AC transformer technology. This results in a new kind of electrical grid, which allows flexible interconnection of all consumers and generators and unhindered energy flow by means of DC power, rather than AC. This new grid will safeguard the future energy supply system that has a high share of fluctuating and decentralized renewable energy sources.

"Research for the grids of the future" – with this motto FEN Research Campus aims to achieve this vision. Therefore, FEN Research Campus researches and develops innovative grid technologies to ready electrical grids for a high share of fluctuating and decentralized renewable energy sources. No doubt, direct current technologies play a key enabling role.
FEN Research Campus is a joint association comprising fifteen research partners of RWTH Aachen University and over twenty industrial partners.

FEN Research Campus is funded by Public Private Partnership (PPP) for Innovation Initiative “Forschungscampus – öffentlich-private Partnerschaft für Innovationen” of the German Federal Ministry of Research and Education (BMBF). With this funding initiative, BMBF supports universities and companies that are working collaboratively on complex areas of research on a long-term basis.

The approach of FEN Research Campus is to combine a wide range of research disciplines and industry branches to enable a holistic research and development approach related to all aspects of future electrical utility networks.

The joint research of academia and industry under one roof in the "FEN Think Tank" facilitates an efficient exchange of knowledge between the partners. To successfully cope with the challenges of our future energy supply, this transdisciplinary approach of pooling experience and disciplines is a necessary and promising way to achieve innovation beyond the limits of a single competence. In addition, the joint research under one roof promotes application-oriented research: results can be quickly transferred into innovative products or services by the industrial partners.

The research activities of FEN Research Campus are located at RWTH Aachen Campus Melaten. In the “FEN Think Tank” each expert has its own workplace in a modern, light-flooded office space where university researchers and company partners work immediately together. The office, located on the fifth floor, offers a panoramic view over RWTH Aachen Campus Melaten. E-bikes, an E-scooter and an E-car allow FEN members to move around the campus easily and quickly, e.g. to reach the test facilities RWTH Aachen University institutes.

RWTH Aachen Campus Melaten is also the location where our planned Medium-Voltage DC Research Grid will be built. This distribution grid will interconnect several multi-megawatt test-benches of different RWTH Institutes (see page 31/32).
About us

FEN Research Campus is organized in three consortia, each associated with the main voltage levels (low-, medium- and high-voltage) of electrical utility grids. Each consortium is headed by a professor of RWTH Aachen University (see picture with structure FEN below). Each consortium is staffed with researchers of the fifteen RWTH Aachen University partners and industrial partners.

Furthermore, each consortium has its own steering committee, which consists of the university and associated industrial partners. Each steering committee assembles four times a year for reviewing research activities and taking decisions. During a meeting, the university partners present their current research status to the industrial partners and together they discuss the next steps. Besides, industrial partners decide on new research projects and take decisions on patents as well as on the admission of new research partners.

In addition to the steering committees, a scientific advisory board is formed of the leaders of the three consortia and elected industrial partners. It meets also four times a year and gives recommendations to the steering committees concerning research projects, research roadmaps and the acquisition of patents.
FEN GmbH coordinates and organizes all activities of FEN Research Campus. It provides the operative environment of FEN Research Campus, like office space, project support, IT services, public relations, meetings and workshops. It is also the central contact for the university and industrial partners.

FEN GmbH is controlled by the supervisory board, which consists of the Rector of RWTH Aachen University, a board member of the Forschungszentrum Jülich and three professors of RWTH Aachen University.

**Members of Scientific Advisory Board**

- Univ.-Prof. Antonello Monti Ph.D., Chairman of LV Consortium
- Univ.-Prof. Dr. ir. Dr. h. c. Rik W. De Doncker, Chairman of MV Consortium
- Univ.-Prof. Dr.-Ing. Albert Moser, Chairman of HV Consortium
- Univ.-Prof. Dr. phil. Eva-Maria Jakobs, Human-Computer Interaction Center (HCIC)
- Dr. Reinhold Bayerer, Infineon Technologies AG
- Robert Heiliger, E.ON SE
- Dr. Sylvio Kosse, Siemens AG
- Holger Krings, Phoenix Contact GmbH
- Dr.-Ing. Christian Haag, CEO FEN GmbH (passive)
- Dr.-Ing. Peter Lürkens, CSO FEN Research Campus (passive)
Our Research Fields

Grid Planning and Operation

Cloud Platform for Smart Energy Services

Automation and Control

Power Conversion and Components

Standards and Regulations

Society, Economics and Health
Our Research Fields

Grid Planning and Operation

The scientists of FEN Research Campus conduct research on procedures and methods for the planning and operation of pure DC grids and hybrid AC-DC grids. Besides the identification of adapted planning criteria for DC grids, the repercussions on the systems of the super- and subordinate conventional AC grids are analyzed.

For this purpose, a Medium-Voltage DC Research Grid at RWTH Aachen Campus Metluten will be constructed and operated initially in test mode. From these experiences, knowledge regarding both the operation of DC grids and the interoperability of the individual components will be gained and the further research and development needs for DC grids shall be identified.

Cloud Platform for Smart Energy Services

In this research field the scientists work on the implementation of a cloud platform for smart energy services. Via standardized communication links, energy profiles and projections about load and generation can be shared with a supervisory entity. This entity efficiently manages consumers and producers using a software platform. Typical examples are links to virtual power plants or services like demand response or demand side management. Innovative energy services will be developed according to the industrial partners’ requirements.
Grid automation and control is a further essential research field. The scientists conduct research regarding grid automation concepts and technologies for DC grids with the integration of decentralized power generation and smart homes. The aim is an automated network using DC technology across several buildings, in order to ensure a power supply in which decentralized generation and load cooperate in an optimal way.

In this research field electrical components and systems, which are necessary for the structure and the operation of DC grids, are investigated and developed. This includes the analysis of materials (e.g. semiconductor and insulation materials) and subcomponents (e.g. semiconductor devices and converters) up until the development of systems such as DC-to-DC converters, circuit breakers and control technology, which will be designed, simulated, installed and tested in the Medium-Voltage DC Research Grid at RWTH Aachen Campus Melaten. During the first phase of FEN Research Campus, the research grid will be built primarily using standard components from the industrial partners’ current portfolios, so that test operations can be conducted as soon as possible. Individual subcomponents will be newly developed.
FEN Research Campus actively contributes to the development and international establishment of standards and norms for DC grids and components. So far, standards and norms fully exist solely for the current AC distribution grid. In order to ensure high safety and reliable, legitimate and hence commercially efficient frameworks, it is necessary to define suitable standards for DC grids and components as well.

For this purpose, FEN Research Campus participates in working groups of "International Council on Large Electric Systems (CIGRE)" and of "Deutsche Kommission Elektrotechnik Elektronik Informationstechnik (DKE)".

Besides the technical research topics, scientists in FEN Research Campus analyze the DC grids regarding non-technical factors. These include, amongst others, social acceptance as well as health, ecological, urbanistic and economical aspects.
## Our Partners
### University Partners

<table>
<thead>
<tr>
<th>Institute</th>
<th>Professor</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCIC, Textlinguistics and Technical Communication</td>
<td>Prof. Dr. phil. Eva-Maria Jakobs</td>
</tr>
<tr>
<td>Institute for Applied Geophysics and Geothermal Energy</td>
<td>Prof. Dr. rer. nat. Christoph Clauser</td>
</tr>
<tr>
<td>Institute for Automation of Complex Power Systems</td>
<td>Prof. Antonello Monti, Ph.D.</td>
</tr>
<tr>
<td>Institute of Electrical Machines</td>
<td>Prof. Dr.-Ing. Dr. h. c. dr hab. Kay Hameyer</td>
</tr>
<tr>
<td>Institute for Energy Efficient Buildings and Indoor Climate</td>
<td>Prof. Dr.-Ing. Dirk Müller</td>
</tr>
<tr>
<td>Institute for Future Energy Consumer Needs and Behavior</td>
<td>Prof. Dr. rer. soc. oec. Reinhard Madlener</td>
</tr>
<tr>
<td>Institute for High Voltage Technology</td>
<td>Prof. Dr.-Ing. Armin Schnettler</td>
</tr>
<tr>
<td>Institute of Industrial Engineering and Ergonomics</td>
<td>Prof. Dr. phil. Martin Frenz</td>
</tr>
<tr>
<td>Institute of Landscape Architecture</td>
<td>Prof. Dr.-Ing. Frank Lohrberg</td>
</tr>
<tr>
<td>Institute and Out-patient Clinic of Occupational Medicine</td>
<td>Prof. Dr. med. Thomas Kraus</td>
</tr>
<tr>
<td>Institute of Political Science</td>
<td>Prof. Dr. phil. Emanuel Richter</td>
</tr>
<tr>
<td>Institute for Power Electronics and Electrical Drives</td>
<td>Prof. Dr. ir. Dr. h. c. Rik W. De Doncker</td>
</tr>
<tr>
<td>Institute for Power Generation and Storage Systems</td>
<td>Prof. Dr. rer. nat. Dirk Uwe Sauer</td>
</tr>
<tr>
<td>Institute of Power Systems and Power Economics</td>
<td>Prof. Dr.-Ing. Albert Moser</td>
</tr>
<tr>
<td>Institute for Urban and Regional Planning</td>
<td>Prof. Dipl.-Ing. Kunibert Wachten</td>
</tr>
<tr>
<td>Company</td>
<td>Name</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>AixControl</td>
<td>Dr. Jochen von Bloh</td>
</tr>
<tr>
<td>ASM TERNI</td>
<td>Massimo Cresta</td>
</tr>
<tr>
<td>B.A.U.M Consult</td>
<td>Alexander von Jagwitz Ludwig Karg</td>
</tr>
<tr>
<td>Bouygues Energies &amp; Services</td>
<td>Antoine Besson Servan Lacire</td>
</tr>
<tr>
<td>CryptoTec</td>
<td>Stephan Krantz Sebastian Chrobak</td>
</tr>
<tr>
<td>E.ON</td>
<td>Robert Heiliger</td>
</tr>
<tr>
<td>ESA Elektroschaltanlagen</td>
<td>Peter Siegel</td>
</tr>
<tr>
<td>ESKA Erich Schweizer</td>
<td>Annette Schweizer-Leischner Jan Eckhardt</td>
</tr>
<tr>
<td>Fuji Electric Europe</td>
<td>Yoshinobu Sato</td>
</tr>
<tr>
<td>GE Energy Power Conversion</td>
<td>Dr. Stefan Schröder Dr. Jörg Janning</td>
</tr>
<tr>
<td>Hager Group</td>
<td>Dr. Torsten Hager</td>
</tr>
<tr>
<td>Hitachi Europe</td>
<td>Tomoyuki Hatakeyama</td>
</tr>
<tr>
<td>Company</td>
<td>NP</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hyosung Corporation</td>
<td></td>
</tr>
<tr>
<td>Infineon Technologies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Infineon Technologies Bipolar</td>
</tr>
<tr>
<td>MR Maschinenfabrik</td>
<td></td>
</tr>
<tr>
<td>Reinhausen</td>
<td></td>
</tr>
<tr>
<td>Murata Manufacturing</td>
<td></td>
</tr>
<tr>
<td>National Instruments</td>
<td></td>
</tr>
<tr>
<td>Phoenix Contact</td>
<td></td>
</tr>
<tr>
<td>Schaffner Deutschland</td>
<td></td>
</tr>
<tr>
<td>Siemens</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Sprint Capital</td>
<td></td>
</tr>
<tr>
<td>Vacuumschmelze</td>
<td></td>
</tr>
<tr>
<td>Westnetz</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Low-Voltage (LV) Consortium focuses on electrical energy, storage and distribution and the automation thereof at low-voltage level. The experts in the LV Consortium investigate power conversion units, the use of decentralized electrical energy storage and the system-level automation in order to integrate decentralized energy sources. Security and protection of the electrical grid as well as strategies to ensure grid stability are fundamental research aspects.

The research on LV grid automation addresses architectures and technologies for the integration of distributed resources and Smart Homes. The aim is to automate networking across buildings and within the power grid to make the most of available energy in every form including the related flexibility. With particular attention to active distribution networks, the research activities include the design of the automation architecture, the definition of the needed measurement infrastructure and the development of new management and control algorithms. Furthermore, the research work includes the integration of communication technologies. The integration of modern forms of communication, such as LTE, enables innovative solutions for future energy grids. Several services can be defined and developed, e.g.: Storage on Demand, Power Quality Support, Voltage Control, Demand Side Management / Demand Response. Moreover, the FEN Low-Voltage Consortium endeavors to develop industry consensus on standards and communication protocols with the objective to provide interoperability and boost market shares of the partners’ products.

The research on the EU Cloud platform aims at establishing a software platform to foster the technical and business development of energy services. This platform shall integrate the various players of the energy sector, which are also expected to be active in the platform development itself. A first platform implementation and application programming interface (API) is available, as starting point, from the EU FP7 project FINESCE (Future INtErnet Smart utility ServiCEs). The platform will be investigated further within the LV Consortium. Ongoing work includes the integration of grid automation functionality to cloud-based systems, providing manufacturer-neutral operation possibilities without the need for dedicated local computing at substation level.

The components of the distribution network, such as power electronic voltage transformers, protection gear and intelligent connectors for low-voltage DC grids are considered as well. Electronic voltage transformers (DC-to-DC converter) are used in appliances connected to the DC grid or to interface regenerative energy sources and storages to the grid. Furthermore, depending on the application, the electronic transformer is used to provide power and protection control. To enable economically priced and highly efficient voltage transformers with reduced volume and costs, available concepts must be reviewed and the application of new electronic devices involving DC technology have to be validated.
The research on standards aims at the application of standards, which are required for the DC grid in order to provide safety and interoperability. The current electrical AC distribution grid is defined by existing standards. A DC grid with identical energy distribution capability compared to an AC grid has not been realized yet. Also, the DC grid is not specified with the same scope as an AC grid. In addition, the necessary protective measurement and testing procedures are not defined consistently. The dynamic regulation requirements in the DC grid differ from those in the AC grid: In contrast to the AC grid, the dynamics of the network are not determined by the rotating mass of the synchronous generators. In DC grids the control dynamics of electronic DC-to-DC converters are determined by the converter control loop parameters. These aspects should be defined in the context of standardization.

Dipl.-Ing. Hauke van Hoek, Program Manager DC Hardware
Power Electronics and Electrical Drives (ISEA)
Jägerstr. 17/19
52066 Aachen

Phone: +49 241 80 99562
Email: hvh@isea.rwth-aachen.de

Dipl.-Ing. (FH) Christoph Loef, Program Manager Standards
Power Electronics and Electrical Drives (ISEA)
Jägerstr. 17/19
52066 Aachen

Phone: +49 241 80 96978
Email: clo@isea.rwth-aachen.de

Dipl.-Ing. Bettina Schäfer, Program Manager Software
Institute for Automation of Complex Power Systems (ACS)
Mathieustr. 10
52074 Aachen

Phone: +49 241 80 49714
Email: bschaefer@eonerc.rwth-aachen.de
The project “Low-Voltage DC Landscape” was carried out in 2016, providing an analysis of DC technology research and implementation at low-voltage level. The study aimed at identifying the variety of application fields for low-voltage DC grid technology and the impeding challenges and associated market potentials.

The analyzed fields of applications span from distribution-level grids, building-level grids and device-level grids to transportation, electrification of remote areas, telecommunications and industrial applications. As an example, the study compares an AC grid versus a DC grid and provides efficiency values in building applications in both grid types.

In extension to this, references to the field of applications investigated are given by literature references and example applications. The given market potentials in each of the investigated market fields can be utilized for further research activities.

The DC grid is often associated with higher efficiency in power systems due to the elimination of rectification and filter layers in distributed power supplies. This holds particularly true for commercial applications with high electricity costs. Depending on the field of application, other benefits may accrue or even dominate a potential choice for LVDC grid concepts. Thus, a key motivation in the discussion of LVDC approaches for distribution-level grids is to deal with the increasingly bidirectional power flow resul-
ting from the progressive proliferation of DC grids at low- and medium-voltage levels. In the built environment, in close proximity to the end-users, ecological motives as well as enhanced convenience through advanced DC-based connectivity technologies (PoE, USB Power Delivery) exert substantial driving forces for LVDC grid infrastructure as well. In remote areas without connection to the centralized supply grid, a social component is added to the bouquet of motivating factors. Effectively, LVDC distribution concepts facilitate the installation of micro- and nanogrids for a basic level of electrification. One of the main benefits in this context is their inherent compatibility with onsite renewable energy resources and DC appliances that are usually strongly represented in solar home systems. This makes the installation of dedicated island grids powered by DC grids a lot simpler compared to alternative AC concepts. In addition, the possibility of having a scalable platform makes LVDC grids more attractive, since it allows the system to be expanded incrementally. However, challenges in standardization, public perception, and financial restrictions have to be overcome to realize the potential of LVDC grids in remote areas.

### Automation Architecture in FIWARE Cloud

The project “Automation Architecture in FIWARE Cloud” examines and preliminarily demonstrates the feasibility of implementing grid automation using the Cloud-computing developments. Results from both the FP7 project IDE4L (Ideal grid for all) as well as from FP7 FINESCE were exploited to create a Future Internet-based cloud platform implementation based on FINESCE results with parts of the developed automation architecture from IDE4L. During the project, options for implementing the Distribution Grid functionality in a Cloud-based infrastructure have been analyzed in terms of the IEC 61850 communications architecture to the cloud. In particular, all the data processing functions defined for the IDE4L use case “Low-Voltage Real-time Monitoring” were implemented in the Cloud system. The Cloud system is based on the open-source OpenStack Cloud and was built using open-source FIWARE components. This implementation is re-usable and shall be extended in further projects.
Low-Voltage Consortium
Research Projects

**FIAlxEnergy**

Since August 2015 the FEN GmbH participates on behalf of the LV Consortium in the BMWi project FIAlxEnergy with the work packages “conception of local production clusters” and “conceptual design and development of solutions for power distribution”. The aims of this three-year project are to develop a method for the automated clustering of different production units taking advantage of bundling effects as well as to determine the flexibility that can be offered on the FIAlxEnergy platform. One effect can be, to counteract imbalances by aggregating different load and production curves. By forecasting the energy consumption, the power generation can be adjusted to optimally match supply and demand.

On the demand side small to large size industry businesses are clustered automatically to evaluate the overall flexibility attributes. A further research area in the scope of the FIAlxEnergy project deals with the business potential of the presented energy cluster. Forming a new platform which bundles the existing energy products from electricity and reserve market serves as an alternative for a separate flexibility market. The platform should be interoperable and smart, offering all participants to exchange information without breaching any data security concerns. The Smart Grid Architecture Model (SGAM) serves as one tool to follow this key criterion.

In 2016 the cooperation between the consor-tial partners has been intensified with regard to the focus areas. A deep analysis has been made to identify the most relevant flexibility patterns on an industrial cluster-level. The analysis involves a classification of various power generation technologies, their real output and predictability. Besides energy sources, also storage technologies have been analyzed in order to evaluate their possible contribution to a flexible electric system.
RESERVE (Renewables in a Stable Electric Grid) has received funding from the European Union’s Horizon 2020 research and innovation program. The project RESERVE aims at developing new techniques and solutions based on 5G technology in order to ensure a more stable operation of the future energy system with a high proportion of renewable energy sources. RESERVE will address this challenge by researching new energy system concepts, implemented as new system support services enabling distributed, multi-level control of the energy system using pan-European unified network connection codes. Near real-time control of the distributed energy network will be enabled by innovative 5G based ICT. Energy system use case scenarios supplied by energy providers will form the basis of energy system models. Performance characteristics of the new control mechanisms will be investigated through integration of energy simulations and live 5G communications.

As one project partner, FEN GmbH, on behalf of the LV Consortium, is leader of the work package dedicated to the communication and dissemination activities. In this role, FEN will develop the necessary communication interfaces, like workshops between the project participants and the public, stakeholders as well as interest groups. The goal is to create awareness of the concepts, technologies and innovation activities within the project. Moreover, it supports the active cooperation with the relevant stakeholders, in particular with the energy community, to ensure constant feedback to the project and to prepare the ground for large-scale uptake of the project results.

**Funding Organization:**
European Commission

**Duration:**
October, 2016 - October, 2019

**Grant total:**
4.997.000 €

**Grant Agreement No:**
727481
ASM TERNI

ASM TERNI S.p.A. is a public multi utility company, established in 1960 and fully owned by the Terni municipality, specializing in water, gas, electricity and environmental services. It supplies water and gas to 86,000 and 50,000 customers respectively and owns and operates the local power distribution network, delivering about 400 GWh to 65,100 customers annually. In the field of waste management, ASM TERNI provides eight districts with solid waste collection services, waste disposal, transportation and street sweeping. Since 2000, ASM TERNI has been involved in pioneering actions aiming to innovate services and infrastructures. In 2010, an Innovation Department was created and currently, thanks also to the EU contributions received under FP7 and H2020 programs, ASM TERNI is considered an important pilot site in Europe to test in real case situation innovative solutions, methods, practices and technologies.

CryptoTec

The owner-managed company CryptoTec AG develops and sells highly encrypted communication softwares for cooperation, cloud storage, and distributed critical infrastructure. Digital signatures, end-to-end encryption, and an automated public key infrastructure are the starting points for the development of a concept for a closed group of users. Providing M2M communication, symmetrical and asymmetrical encryption, and the highest standards of security, it is still very easy to use. Administrators as well as companies and private users rely on the cryptographic security solutions developed by CryptoTec.

CryptoTec AG invests a great amount in having its software examined by external auditing companies. All auditing companies and internationally recognized white hat hackers confirm that they have not found a single point of attack which would enable the system to be infiltrated. They attest to the absolute security of CryptoTec.

In addition to the central office in Cologne, the company has offices and subsidiaries in India and Hong Kong.
ESKA Erich Schweizer

Founded in 1948 the **ESKA Erich Schweizer GmbH** has an experience of nearly 70 years. ESKA is the only one who is producing fuses and fuseholders in Germany. The fully automated production is located in Kassel. Here ESKA is producing all kinds of miniature fuse links with all the sizes which are requested from the customers such as 5 x 15 mm; 6.3 x 32 mm e.g. and of course the most important size 5 x 20 mm. With a wide network of distribution and sales agencies, the products are sold all over the world.

With its own R & D department, ESKA is able to face all new challenges and can also offer specific or individual product developments to the customers on the basis of their requirements.

ESKA is a competent, innovative and reliable partner in the field of current-, overvoltage and temperature protection. The focus of ESKA is on the safety of your products.

Murata

**Murata Manufacturing Co., Ltd.** is a worldwide leader in the design, manufacture and sale of ceramic-based passive electronic components & solutions, communication modules and power supply modules. Murata is committed to the development of advanced electronic materials and leading edge, multi-functional, high-density modules. The company has employees and manufacturing facilities throughout the world.
Low-Voltage Consortium
New Industrial Partners

National Instruments

Since 1976, National Instruments has made it possible for engineers and scientists to solve the world’s greatest engineering challenges with powerful, flexible technology systems that accelerate productivity and drive rapid innovation. Customers from a wide variety of industries – from healthcare to automotive and from consumer electronics to particle physics – use National Instruments’ integrated hardware and software platform to improve the world we live in.

Contact
Marc Backmeyer
+49 89 741313165
marc.backmeyer@ni.com

PHOENIX CONTACT

Phoenix Contact, a family-owned company, is the worldwide market leader of components, systems and solutions in the area of electrical engineering, electronics and automation. The product range comprises components and system solutions for many different industries. A diverse product range of modular terminal blocks, printed circuit terminal blocks, cable connection technology and installation accessories offers innovative components. Electronic interfaces and power supplies, automation systems, safety solutions, IT security solutions, surge protection systems as well as software programs and tools provide users with comprehensive systems. The automotive, renewable energy and infrastructure markets are supported with holistic solution concepts including engineering and training services and further service features according to their specific demands.

Contact
Holger Krings
+49 52 819462512
hkrings@phoenixcontact.com
<table>
<thead>
<tr>
<th>Low-Voltage Consortium</th>
<th>Overview Industrial Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASM TERNI</strong></td>
<td>Massimo Cresta</td>
</tr>
<tr>
<td><strong>B.A.U.M Consult</strong></td>
<td>Alexander von Jagwitz Ludwig Karg</td>
</tr>
<tr>
<td><strong>Bouygues Energies &amp; Services</strong></td>
<td>Antoine Besson Servan Lacire</td>
</tr>
<tr>
<td><strong>CryptoTec</strong></td>
<td>Stephan Krantz Sebastian Chrobak</td>
</tr>
<tr>
<td><strong>ESA Elektroschaltanlagen</strong></td>
<td>Peter Siegel</td>
</tr>
<tr>
<td><strong>ESKA Erich Schweizer</strong></td>
<td>Annette Schweizer-Leischner Jan Eckhardt</td>
</tr>
<tr>
<td><strong>Hager Group</strong></td>
<td>Dr. Torsten Hager</td>
</tr>
<tr>
<td><strong>Murata Manufacturing</strong></td>
<td>Markus W. Huschens</td>
</tr>
<tr>
<td><strong>National Instruments</strong></td>
<td>Marc Backmeyer</td>
</tr>
<tr>
<td><strong>Phoenix Contact</strong></td>
<td>Holger Klings</td>
</tr>
<tr>
<td><strong>Siemens</strong></td>
<td>Dr. Sylvio Kosse Mathias Maerten</td>
</tr>
<tr>
<td><strong>Sprint Capital</strong></td>
<td>Yamada Hikaru</td>
</tr>
<tr>
<td><strong>Vacuumchmelze</strong></td>
<td>Dr. Ralf Koch</td>
</tr>
</tbody>
</table>
In the Medium-Voltage (MV) Consortium the capabilities of DC technology within the medium-voltage level, including the interfaces to AC systems as well as to high and low-voltage levels, are analyzed. Cable connections, solutions for network automation, -control and -stability, as well as other necessary components for a flexible distribution of the energy are main topics of research.

The main objective of the consortium is the construction of a Medium-Voltage DC Research Grid at RWTH Aachen Campus Melaten, where various test benches in the megawatt range from different institutes will be connected. Experts carry out field tests on electrical components, such as cables and DC-to-DC converters, but also (hybrid) switchgear. Furthermore, different control, operation and protection concepts are under investigation.

Medium-voltage distribution grids are a very important part of the electrical supply system. Energy that is generated in large power stations is transmitted via high-voltage lines and then fed into medium-voltage grids to reach the customers. The grid today is meshed, i.e. interconnected, only at the transmission level, i.e. the high and very high-voltage level (typically 220 kV and above). In contrast, medium- and low-voltage AC distribution grids are arranged radially or as open ring bus structures. A flexible energy transfer between different medium-voltage substations, e.g. between different city quarters or small towns, cannot be realized with today’s three-phase AC system.

Key problems in classical distribution grids are the fluctuating load and the reverse flow of power that occur during variable and strong feed-in situations of renewable power sources. AC grids were optimized for a top-down power flow and are subject to voltage variations, in particular to overvoltages under reverse power flow conditions. Furthermore, coupling of separate distribution grids requires control of the grid parameters at the end points of the coupling link, due to the dependency of the power flow to frequency, phase and voltage.

5MW DC-to-DC medium-voltage converter at E.ON Energy Research Center
DC grid technology does not have frequency and phase at all. Only voltage governs its behavior, thus simplifying the task of connecting grid segments substantially. As DC grids intrinsically use controlled converters at its substations, an additional degree of controllability becomes available that allows handling fluctuating power and reverse power flow with much higher flexibility.

Another advantage of DC grid technology is its independence of the standardized AC grid frequencies (50 or 60 Hz). In an AC grid frequency is crucial for the size, weight and eventually cost of transformers. Their equivalent in DC grids are DC-to-DC converters, performing the function of voltage transformation between different voltage levels. DC-to-DC converters still use transformers internally which can be designed freely for operation at the best suitable frequency, which is substantially higher than the standard grid frequency. This eventually results into enormous savings of copper and magnetic steel, expected up to 90%.

The Medium-Voltage Consortium is part of FEN Research Campus and since end of 2014 receives support from the funding initiative “Forschungscampus – öffentlich-private Partnerschaft für Innovationen” of Federal Ministry of Education and Research (BMBF). With this initiative, BMBF supports universities and companies that are working collaboratively on complex areas of research on a long-term basis. It is of vital importance that those areas possess high innovation potential and societal relevance.

Four connected projects (see following pages) are funded with € 10 million for an initial period of five years by BMBF with this funding initiative. There is an outlook of another grant of twenty million Euros from the Ministry for extending research in following phases after successful completion of the current phase.
Traditional crafts as civil engineering, gardening, traffic planning. A manual on impact factors of DC grid technology on landscaping was created. Metrics of influential effects of DC grid technology (costs, reliability, ownership, regional autonomy, and appearance) on acceptance of citizens were investigated by means of a Choice Experiment on a representatively structured group of 1565 participants, which allows to differentiate between relevant and irrelevant factors in regards to acceptance of new grid technologies in general by citizens.

Physiological studies have investigated the interference of magnetic fields from DC grids on the human body and medical implants by simulations and shown that effects are not to be expected for the investigated field strengths. Simulation results concerning the impacts in the human body are shown in figure.

The text and web mining studies during the last period allow automatically processing large amounts of text in natural language, in the present case with the purpose to retrieve public opinions regarding lines of DC grids. This is achieved by evaluation of user comments in social media. The studies give information on subjectively perceived risks of DC grids. The results reveal chronological trends, relations to locations and differences between stakeholder groups.

A significant proportion of the project concentrated on fault conditions, protection, selectivity and influence on overall grid reliability. A special topic for DC grids are leakage currents, which over time can produce damage to nearby construction, if not handled properly.

In the field of socio-technical research potential effects of DC grid technology on landscape and urban development have been studied, identifying interdisciplinary relationships to

**Medium-Voltage Consortium**

**Research Projects**

**Modelling, Planning, Conceptual Design and Assessment of Future Grids (FEN P1)**

FEN P1 is led by the Institute of Power Systems and Power Economics (IAEW). In this interdisciplinary project electro-technical as well as socio-technical aspects are addressed. Regarding the technical aspects, one field of research focuses on developing an expansion as well as a target grid planning methodology for DC grids. After finishing preliminary analyses, a new methodology for planning distribution grids, which leads to a cost-minimized and technically feasible grid for a given supply task with application of DC grid technology, has been developed. Work on extensions to include the new operational degrees of freedom and special characteristics of protection function for DC grids was started. Similar work has been done on the mitigation of grid loading and losses by applying the controllability features of grid node converters. Another topic connected to the controllability in DC grids is the control stability of and control design in the DC grid for dynamic time range in presence of a large number of cooperatively operating converters at fluctuating grid load and feed-in situations, especially for a high penetration of renewables.

A significant proportion of the project concentrated on fault conditions, protection, selectivity and influence on overall grid reliability. A special topic for DC grids are leakage currents, which over time can produce damage to nearby construction, if not handled properly.

In the field of socio-technical research potential effects of DC grid technology on landscape and urban development have been studied, identifying interdisciplinary relationships to...
Electrical Equipment and Grid Technologies (FEN P2)

FEN P2, led by the Institute Power Generation and Storage Systems (PGS), investigates new materials and components and their effects on converter and system level. Research on DC-to-DC converters has been concentrating on new topologies of high-power converters for medium-voltage DC substations (e.g. 5 MW). For high efficiency and low EMI interference soft switching is implemented and investigated. A demonstrator for 5 MW at 5 kV input and output voltage is being designed. Eventually, it will be tested within the medium-voltage research grid (FEN P4). A fault-tolerant control algorithm allows continued operation of converters in case of failures even of several semiconductor switches. This leads to a significant increase of operational availability of substations with DC-to-DC converters.

A multiport converter targeting the transition between the medium- and low-voltage level has been realized and is currently under test. This converter interfaces the 5 kV medium-voltage level with the low-voltage domain and can provide two controlled secondary levels (380V and 760V) simultaneously. By using silicon carbide components at the 5 kV port, advantage is taken from high switching frequencies, leading to small converter size and high efficiency.

A critical function in utility grids are circuit breakers and power switches which have an important role in the protection concept. Unlike AC grids, DC grids do not have a natural zero crossing of voltage and current, which is a feature upon which AC technology heavily relies. Several concepts of DC switches have been considered and point towards hybrid concepts, i.e. combinations of mechanical and semiconductor switches. Test facilities have been created which allow testing of these components at rated voltage and current.

Medium-frequency transformers offer efficient voltage transformation and galvanic isolation. Their operation at elevated frequency leads to savings of copper and steel in their construction. Different core materials have been investigated under different operation frequencies and under non-sinusoidal excitation. A multi-objective genetic algorithm has been developed, that allows efficient optimization of several design parameters simultaneously for a given cost function, e.g. trade-off between losses and weight.

A key topic in DC grids are the cables and their behavior underground. Meanwhile, heating of cables has been investigated in detail. While the behavior of the cable itself is rather simple, the reaction of the soil to the heat, which is produced by the cable, is very complex. Complex heat and water flow processes in combination with local evaporation could be simulated with a special simulation program. The results help to estimate load limitations for buried cables much better than the existing rule-of-thumbs methods.

Silicon-carbide converter module
FEN P3 is led by the Institute for Automation of Complex Power Systems (ACS). This project focuses on the development of novel control concepts and automation architectures for pure DC and hybrid AC-DC systems.

In the last period appropriate automation and grid control system architectures were investigated. In view of the new possibilities of control features in regard of voltage and power distribution control, the requirements of such a system correlate strongly with the roles of the various actors in the eco-system, as consumers, producers, metering organizations etc. German regulations and rulings e.g. the EnWG, the EEG, and others have been analyzed. Then relevant business models for operators of advanced medium-voltage DC grids were investigated. E.g. at the boundary between a DC and an AC grid, the DC grid converters may provide reactive power to the HVAC grid and thus provide support to voltage control in the AC domain.

For the monitoring task a robust state-estimator has been developed which allows to compensate errors of individual sensors. Optimal locations of sensors were identified and methods created to utilize the data from the control systems of the power electronic converters (IED-converter). Eventually, the method allows to reduce the number of sensors without losing confidence.

One major aim of research is the development of system models for offline and real-time simulation tools to analyze the dynamic operation under small and large disturbances. The models must feature electromechanical transient behavior, as well as the switching dynamics of converters. A first set of component models has been developed. The modeling of specific components like the dual active bridge DC-to-DC converter is implemented in close cooperation with the institute PGS.

The control concepts are developed in a hierarchial framework. The operation of the primary controllers (component level) is coordinated by the secondary-level control structure (system level). The coordination approach is defined by the control strategy, in centralized, decentralized or distributed architectures, and is realized by the automation system. These concepts are compared thus deriving the best option for the demonstrator grid. These developed control concepts must meet operational and control requirements, which are to be determined in the project, for the case of terrestrial medium-voltage DC systems (MVDC). A preliminary comparison of available control approaches, best suited for MVDC and hybrid power grids has been performed.

The automation system consists of four key-elements, namely monitoring system, controlling system, communication system and data platforms with standardized data models. For designing the automation architecture, the interactions between these four key-elements have first to be defined. The different control functions, which the automation system should perform, are defined as individual use-cases. These use-cases are harmonized using the Use Case Methodology (UCM) and represented using the Smart Grid Architecture Model (SGAM), which allows technologically neutral analysis of the automation architecture. Experiences from state-of-the-art automation approaches for ac grids have been already partially mapped to DC grids.
with the necessary modification of use-cases. Existing Hardware-in-the-Loop (HiL) platform and a scaled-down Power-Hardware-in-the-Loop (PHIL) platform have been extended to test and validate the control concepts and the automation architecture. The HiL platform comprises real-time power system simulation (with the models developed in this project) and industrial measurement and control devices. The PHIL test-platform is a multi-terminal low-power lab network, which can emulate the dynamics of the FEN medium-voltage DC grid demonstrator of FEN P4.

The purpose of this platform is to test the grid control and management principal at a safe level and eliminate risk of damage. Instead of megawatts, the total installed power is only 11 kW. Four converters set up the proposed DC grids topology. The future medium-voltage DC test grid, which is currently under design with a bus voltage of +/-2.5 kV, is represented by a DC bus of +/-380V. One converter connects to the “legacy” AC grid, the other three to the individual points of load (PV generator, storage battery, and consumer). These are operated at a low-voltage of appr. 48 V.

Design, Construction and Testing Campus FEN Research Grid (FEN P4)

FEN P4, led by the Institute Power Generation and Storage Systems (PGS), implements the design and the realization of a full scale medium-voltage distribution grid. This infrastructure demonstrator is a 5 kV multi-terminal grid, which will be built and used for research purposes at RWTH Aachen Campus Melaten. This grid will interconnect several multi-megawatt test-benches of different RWTH Institutes. Since the power-electronic converters allow bidirectional power flow, energy can be exchanged internally among the test-benches and externally by drawing or injecting energy from or into the public electricity grid.

The research grid will be built using standard converters produced by FEN industry partners. The aim is to demonstrate the feasibility of medium-voltage distribution grids using state-of-the-art technology and to gain experiences with the operation of an MVDC grid. Finally, prototype components of DC-to-DC converters, circuit breakers or DC cables can be investigated by connecting them to the research grid for testing purposes.

In a workshop with the partners from industry suitable components for the implementation of the grid were identified, which are fit for the defined performance specifications. These comprise converters, cables, transformers and the monitoring and communications sub-system.

A significant proportion of the work has been spent on the control task, which is crucial for maintaining the stability of the research grid.
Medium-Voltage Consortium
Research Projects

Despite absence of inertia in DC grids power balance has to be maintained at any time, which requires very fast and accurate control. To develop this, industrial partner AixCon- trol provided a real-time platform that allows real-time testing of the controller together with a real-time simulation of the plant (the converter) in this case. In a later phase, the real-time simulator will be replaced by the converter hardware.

A cost effective and redundant solution of the DC grid protection functions was developed. The reliability of the research grid has been investigated in regard to several different protection concepts, by utilizing published data on reliability of power electronic systems and other grid components. It could be shown, that selection of protection concepts primarily based on economic aspects does not lead to relevant disadvantages in the reliability of the electrical supply system.

The grid topology and routing was finalized eventually together with infrastructure stakeholders at the location of FEN Research Campus and the quotation process for the construction planning and groundworks was started.

Seed Fund Projects
Seed Fund Projects are short studies which are funded by FEN Research Campus itself, supported by industry partners. These projects investigate specific questions, not covered in the larger publicly funded projects, or perform initial evaluation of potential new research directions, to be followed up subsequently in a larger context. During the year 2016 altogether two Seed Fund Projects were finalized by teams from several institutes from the RWTH Aachen University. The Seed Fund Projects covered a wide range of different topics.

Project 11
In this project a comparison of the loading of AC lines and DC lines was investigated and the effects on power capacity at comparable cable dimensions was evaluated. This was done on the basis of synthetic grids, based on typical characteristics of existing grid topologies and cable configurations. Further, the operational impact of power electronic parts of DC grids in regard to losses and voltage control was studied.

Project 12
In this project a global survey of related actual activities on medium-voltage DC grid technology was produced. A focus was put on utility technology. A total number of 28 studies and projects were identified, among these are pure R&D studies and theoretical work, as well as projects and demonstrators based on commercial products.
<table>
<thead>
<tr>
<th>Company</th>
<th>Contact Person(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AixControl</td>
<td>Dr. Jochen von Bloh</td>
</tr>
<tr>
<td>E.ON</td>
<td>Robert Heiliger</td>
</tr>
<tr>
<td>Fuji Electric Europe</td>
<td>Yoshinobu Sato</td>
</tr>
<tr>
<td>GE Energy Power Conversion</td>
<td>Dr. Stefan Schröder, Dr. Jörg Janning</td>
</tr>
<tr>
<td>Hager Group</td>
<td>Dr. Torsten Hager</td>
</tr>
<tr>
<td>Hitachi Europe</td>
<td>Tomoyuki Hatakeyama</td>
</tr>
<tr>
<td>Hyosung Corporation</td>
<td>Young Seong Han</td>
</tr>
<tr>
<td>Infineon Technologies Bipolar</td>
<td>Dr. Reinhold Bayerer, Dr. Mario Schenk</td>
</tr>
<tr>
<td>MR Maschinenfabrik Reinhausen</td>
<td>Dr. Uwe Kaltenborn</td>
</tr>
<tr>
<td>Schaffner Deutschland</td>
<td>Frank Bürvenich</td>
</tr>
<tr>
<td>Siemens</td>
<td>Dr. Sylvio Kosse, Mathias Maerten</td>
</tr>
<tr>
<td>Westnetz</td>
<td>Dr. Stefan Nykamp, Mark Schocke</td>
</tr>
</tbody>
</table>
Besides, in distribution grids there are also new applications for DC technology in overlaying high and extra high-voltage networks. This incorporates the DC connections in the "German Power Grid Development Plan" and "Offshore Grid Development Plan" but also the application in high-voltage grids offers potential use cases. DC links could be utilized to couple different high-voltage network groups in order to control the load flow between those groups.

Furthermore, their capability regarding the provision of reactive power could mitigate voltage band violations and improve voltage stability. Another possible future research area could be a meshed offshore grid, connecting Great Britain, Central Western Europe, the Nordic Systems and offshore windfarms.

In order to provide a platform for industrial partners who are interested in research topics related to the application of DC technology in high-voltage as well as extra high-voltage grids a High Voltage Consortium is contemplated. Other than the consortia for medium- and low-voltage there is no need for establishing a new HV Consortium within FEN Research Campus. In fact there is already an existing consortium, "Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft (FGH) e.V.", which is focusing on high- and extra high-voltage grids for many years. Therefore, FEN Research Campus encourages industrial partners interested in this area to join FGH.

Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft (FGH) e.V. is a non-profit research association of electricity supply industry and electrical industry with the aim of developing and providing competence and practice-oriented technical knowledge together with its more than 40 member companies. Among them there are German and Austrian network operators at both transmission and distribution level as well as manufacturers of equipment for electrical networks.

The history of FGH reaches back almost 100 years, still aiming for the support of introduction of the extra high-voltage levels in Germany. From this strong focus on power equipment technology for the extra-high-voltage (EHV) level, the principal activities have evolved into other voltage levels and into the fields of system studies, software development and technical education – always related to electrical power supply networks.

FGH e.V. and its subsidiaries are based in Mannheim and Aachen with about 70 highly qualified employees. Since 2002 there is a strong cooperation between FGH e.V. and RWTH Aachen due to its status as an affiliated institute of RWTH Aachen. But in numerous projects FGH works closely together with other national and international research organizations and universities as well.

The direct integration of network operators and manufacturing industry in the research project planning and execution ensures the practical relevance of these projects, their direct usefulness for the members and a fast transfer of the results. The research topics are initiated and accompanied by the research advisory board that consists of competent experts of the member companies. For the project financing FGH applies for support mainly by public institutions, e.g. the European Commission, the German research association (DFG) and the working group of industrial research associations “Otto von Guericke” (AiF), in which FGH as a non-profit research association exclusively represents the field of activity of its members.
The results of the research projects are particularly valuable for members since they initiate, contribute to and accompany the projects intensively. With broad financing they can use the competence of FGH in order to receive practical solutions for their fundamental and urgent questions.

While research projects still play a main role for FGH, commercial studies and consulting for utilities as well as the development of software solutions for network calculation and the evaluation and failure management are equally important today. FGH can provide renowned expertise for the complete transmission and distribution sector. Starting in 2002 FGH has developed compliance testing procedures for decentralized generators and network components, which still build the basis of corresponding certification processes in Germany.

The recent structural changes and rationalizations have led to a noticeable decrease of the participation of companies in committee work. The FGH experts can at least partly adjust this by being active in many national and international working groups as well as their steering committees.

FGH’s various seminars, which are set up in direct exchange with the member companies, on a wide scope of electrical power engineering issues constitute a hallmark in the German electric power industries.

Dr.-Ing. Hendrik Vennegeerts

Department Director System Studies, Professional Training
Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e.V.
Hallenweg 40
68219 Mannheim

fgh@fgh-ma.de

M.Sc. Jens Priebe

Institute of Power Systems and Power Economics
Schinkelstr. 6
52062 Aachen

+49 241 80 97889
jp@iaew.rwth-aachen.de
Further Cooperations

Facing the Smart Future: Smart Cities & Infrastructure

FEN Research Campus participates in the Consortium Study “Facing the Smart Future: Smart Cities & Infrastructure”. KEX Knowledge Exchange AG and FIR at RWTH Aachen started the project on the 3rd of November 2016.

In cooperation with the most relevant players of the whole value creation chain, the consortium study aspires to create economic and technological transparency and to explore and analyze market and technology trends as well as possibly game-changing business model shifts. The focus areas are: Smart Mobility & Transportation, Smart Infrastructure & Buildings, Smart Living & Work, Smart Governance and Smart Environment & Utilities.

GRAPES

E.ON Energy Research Center (E.ON ERC) at RWTH Aachen University signed a cooperation agreement with US NSF Center for Grid-Connected Advanced Power Electronics Systems (GRAPES) at the University of Arkansas (USA). This agreement establishes cooperation in research on power electronic components in transportation and distribution grids. These topics are related in particular to the research activities of E.ON ERC and FEN Research Campus.

By this agreement, FEN, E.ON ERC and GRAPES conclude to exchange scientific publications and other information of common interest. Academic exchange is also an aspect that is to be further promoted, whereby this particularly addresses the exchange of scientific staff in the fields of research and education. Also students of both universities will benefit from this collaboration. In addition, research topics will be identified in which the necessary investigations and studies will be conducted in close collaboration between the two research facilities. Joint planning and the realization of seminars and conferences are part of the plans of this German-American cooperation.

GRAPES is a research association of institutes of the University of Arkansas, the University of South Carolina, the University of Wisconsin Milwaukee, and industrial partners and is funded by the members of the association and the US National Science Foundation (NSF).

Project Partnerships with the IRR (Innovation Region Rhenish Mining Area)

The Rhenish Mining Area between Cologne, Aachen and Mönchengladbach is the biggest of three lignite mining districts in Germany. This energy hot spot is still characterized by the lignite industry with three great opencast mines and four electric power plants of 10 GW installed power, generating about 70 TWh/a. In order to meet the climate protection goals, the region has to leave the fossil-fuel based
Further Cooperations

energy production. This will have a big impact for the local economy. Therefore, the IRR has been founded as a stakeholder initiative. The main task is to shape the structural change by developing strategies and new business models based on innovation.

In a regional idea competition 75 project ideas have been identified and are now on their way towards implementation. One main field of activity is focusing on the energy transition and new technologies of power generation and grid optimization. In two of these projects, the use of DC-technology is the main principle of innovation. Here FEN Research Campus is an active partner in the respective working groups.

The first project deals with a DC-Grid in the medium-voltage range. The objective is to develop a municipal energy supply and transport system based on renewable sources and efficient DC-technology, supporting attractive e-mobility with ubiquitous fast-charging. Actually, the project consortium is going to be established and agreeing about the individual steps of the project. FEN is accompanying the project leader from RWTH Aachen University, E.ON ERC, who initialized the project idea.

The second one focuses on the implementation of DC-Smart Grids in climate protection estates that are planned in the nearby area of the open pit mines. It is all about showing a way how efficient DC-technology can be integrated in a cellular grid with decentralized renewable energy production. As a partner in the project work group, FEN is contributing to solve open questions concerning feasibility regarding the development of a commercial strategy (e.g business models) for the building sites.
Chronicle 2016

- **14 JAN**: DKE Meeting Standardization Roadmap LVDC, Frankfurt
- **10 FEB**: Zukunftsenergien, Essen
- **15 FEB**: Start FEN Intranet “meinFEN” for FEN partners
- **22 FEB**: Official start of FEN LV Consortium, Aachen
- **20-24 MAR**: Applied Power Electronic Conference (APEC), Long Beach
- **26/27 JAN**: 3rd Conference Zukünftige Stromnetze für Erneuerbare Energien, Berlin
- **10-12 FEB**: EnInnov 2016, Graz
- **15-18 FEB**: E-World energy & water, Essen
- **15-17 MAR**: 10th International Renewable Energy Storage Conference (IRES 2016), Düsseldorf
IEE ENERGYCON, Leuven

04-08 APR

Company outing Michael Schumacher kart track, Kerpen

28 APR

International Instrumentation and Measurement Technology Conference (I2MTC), Taipei

23-26 MAY

Battery Power Day NRW, Münster

25 APR

PCIM Europa, Nuremberg

10-12 MAY

2nd Symposium BMBF Begleitforschung, Berlin

31/01 MAY/JUN

New FEN Website online

01 JUN

CIRED 2016, Helsinki

14-15 JUN

Woche der Umwelt, Berlin

07/08 JUN

Chronicle 2016
Funding approval for the research project RESERVE of the European Commission 20 JUN

19th Power Systems Computation Conference (PSCC 2016), Genoa 20-24 JUN

FEN sponsor at InnoGrid2020+, Brüssels 27/28 JUN

IEEE Workshop on Control and Modeling for Power Electronics, Trondheim 27-30 JUN

7th International Symposium on Power Electronics for Distributed Generation Systems (PEDG), Vancouver 27-30 JUN

Integration of Sustainable Energy Conference (iSEneC), Nuremberg 11 JUL

BMWi Roadshow: Vernetzte Energie aus der Region Aachen, Aachen 04 JUL

IEEE PES General Meeting, Boston 17-21 JUL

Move FEN Think Tank in Photonics Cluster 05 AUG
CIGRE 2016, Paris

05-09 Sep

European Conference on Power Electronics and Applications, Karlsruhe

07 Sep

Conference of Euregio Maas-Rhein: Energie neu denken, Aachen/Heerlen

18-22 Sep

8th Annual IEEE Energy Conversion Congress & Exposition (ECCE 2016), Milwaukee

21-24 Sep

IEEE Conference Transmission & Distribution and Exposition Latin America (TDLA), Morelia

28-30 Sep

IEEE International Workshop on Applied Measurements for Power Systems (AMPS), Aachen

23-25 Sep

Aachen 2025, Aachen

02-05 Oct

IEEE International Professional Communication (ProComm), Austin

30 Sep

Aachener Company Run, Aachen
IEEE Innovative Smart Grid Technologies (ISGT), Ljubljana

IEEE Conference Industrial Electronics Society (IECON), Florence

10th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion, Belgrad

GRAPES Fall 2016 Semi-Annual Industrial Advisory Board Meeting, Fayetteville

IRR-Revierkonferenz, Bergheim

Kick-off Meeting of research project RESERVE of the European Commission, Herzogenrath

Start of Consortium Study Facing the Smart Future: Smart Cities & Infrastructure, Aachen

VDE Congress, Mannheim

European Utility Week, Barcelona
Meeting of BMBF Forschungscampi, Mannheim
05 DEC

FEN Christmas Party, Alsdorf
06 DEC

Funding approval for the research project FISMEP of the European Commission
15 DEC

IEEE Southern Power Electronics Conference (SPEC), Auckland
05-08 DEC

05-08 DEC
Future 2017

FEN Day @ Siemens, Erlangen  
25-26 JAN

E-World energy & water, Essen  
07-09 FEB

Kick-Off-Workshop for the DIN SPEC 91366, Berlin  
22 MAR

New Energy World, Leipzig  
05-06 APR

BMBF Research Campus Workshop, Aachen  
18-19 MAY

RWTH transparent, Aachen  
27 JAN

DKE Experts forum, Mannheim  
21 MAR

Applied Power Electronics Conference and Exposition 2017 (APEC), Tampa  
26-30 MAR

Power Electronics for Distributed Generation (PEDG2017), Florianópolis  
17-20 APR
IEEE International Instrumentation and Measurement Technology Conference (I2MTC), Torino

22-25 MAY

IEEE International Future Energy Electronics (ECCE), Kaohsiung

03-07 JUN

IEEE PES PowerTech Conference, Manchester

18-22 JUN

EU Sustainable Energy Week (EUSEW), Brussels

19-25 JUN

InnoGrid 2020+, Brussels

26-27 JUN

BMBF "Zukunftskongress Energie-offensive 2030", Berlin

23-24 MAY

International Economic Conference (INFER), Bordeaux

07-09 JUN

IEEE Industrial Electronics Society (ISIE), Edinburgh

19-21 JUN

International Conference on Amphibious Architecture, Design and Engineering, Waterloo

25-28 JUN

Future 2017
<table>
<thead>
<tr>
<th>Event Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Conference on DC Microgrids (ICDCM), Nuremberg</td>
<td>27-29 JUN</td>
</tr>
<tr>
<td>IEEE Power &amp; Energy Society General Meeting, Chicago</td>
<td>16-20 JUL</td>
</tr>
<tr>
<td>“Deutscher Energiekongress”, München</td>
<td>05-06 SEP</td>
</tr>
<tr>
<td>EPE’17 ECCE Europe, Warsaw</td>
<td>11-14 SEP</td>
</tr>
<tr>
<td>European Utility Week, Amsterdam</td>
<td>03-05 OCT</td>
</tr>
<tr>
<td>“Diskussionsforum Stromnetze”, Aachen</td>
<td>11 JUL</td>
</tr>
<tr>
<td>Use the additional space of the FEN Think Tank</td>
<td>01 AUG</td>
</tr>
<tr>
<td>“Partnerkongress der Energieforen Leipzig”</td>
<td>05-06 SEP</td>
</tr>
<tr>
<td>IEEE International Conference on Innovative Smart Grid Technologies, Torino</td>
<td>26-29 SEP</td>
</tr>
</tbody>
</table>
Future 2017

**IEEE International Conference on Smart Grid Communications, Dresden**

23-26 OCT

**Publication of the DIN SPEC 91366, Berlin**

01 NOV
### Facts and Figures

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>University Partners</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Industrial Partners</td>
<td>0 LV / 11 MV</td>
<td>8 LV / 12 MV</td>
<td>13 LV / 12 MV</td>
</tr>
<tr>
<td>Researchers</td>
<td>18</td>
<td>36</td>
<td>101</td>
</tr>
<tr>
<td>Office Space</td>
<td>60 m²</td>
<td>260 m²</td>
<td>630 m²</td>
</tr>
<tr>
<td>Projects (publicly funded)</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>
## Publications

<table>
<thead>
<tr>
<th>Publications</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Publications (FEN Research Campus P1-P4)</td>
<td>20</td>
</tr>
<tr>
<td>Further Scientific Publications</td>
<td>35</td>
</tr>
<tr>
<td>Degree Theses</td>
<td>48</td>
</tr>
<tr>
<td>Further Publications and Lectures</td>
<td>20</td>
</tr>
<tr>
<td>Patents</td>
<td>19</td>
</tr>
<tr>
<td>Seed Fund Projects</td>
<td>3</td>
</tr>
</tbody>
</table>

## Budget Finance

### Total Budget from FNP MV (530K€)

- Research Projects: 45%
- Staff: 25%
- Office: 15%
- Administration: 10%
- IPR*: 5%

### Total Budget from FNP LV (230K€)

- Staff: 40%
- Administration: 30%
- Research Projects: 25%
- Office: 5%
- IPR*: 5%

*Intellectual Property Rights
Staff FEN GmbH

Dr. Christian Haag  
Chief Executive Officer  
+49 241 80 22471  
chaag@FENaachen.net

Andrea Backes  
Executive Assistant  
+49 241 80 22471  
abackes@FENaachen.net

Michael Bertenburg, M.Sc.  
IT  
+49 241 80 22476  
mbertenburg@FENaachen.net

Gonca Gürses, M.Sc.  
Research Associate  
+49 241 80 22477  
gguerses@FENaachen.net

Dr. rer. nat. Marina Maicu  
Head of Research Funding Support  
+49 241 80 22472  
mmaicu@FENaachen.net

Laura May, M.A.  
Head of Marketing and Communications  
+49 241 80 22474  
lmay@FENaachen.net
Staff FEN GmbH

Pascal Friedrich
Student Assistant Research
+49 241 80 22471
pfriedrich@FENaachen.net

Maxime Herbord
Student Assistant Marketing
+49 241 80 22471
mherbord@FENaachen.net

Andy Ly
Student Assistant Marketing
+49 241 80 22471
aly@FENaachen.net

Alexander Peeters
Student Assistant Research
+49 241 80 22471
apeeters@FENaachen.net

Ann-Caroline Volkmann
Student Assistant Marketing
+49 241 80 22471
avolkmann@FENaachen.net

Tobias Zentgraf
Student Assistant Research
+49 241 80 22471
tzentgraf@FENaachen.net
Imprint

EDITORIAL & LAYOUT
Dr. Christian Haag, Dr. Peter Lürkens, Bettina Schäfer, Christoph Loef, Gonca Güreses, Dr. Marina Maicu, Ann-Caroline Volkmann, Laura May

PICTURES
© Andrea Boldizsar: street with wind turbine
© E.ON ERC: GRAPES
© GG Films: European Utility Week
© FEN GmbH: exterior view of building
© DDM Company: landscape with wind turbine
© E.ON ERC: DC-to-DC converter (2x)
© Peter Winandy: aerial photograph, real-time network simulator with power-hardware in the loop
© stockWERK/fotolia.com: Energiewende
© vege/fotolia.com: puzzle
© PhotographyByMK/fotolia.com: high-voltage grid
© FEN GmbH: other photos
© FEN GmbH, Freepik and Fotolia (© radoma / Fotolia.com): icons

PRINT
Afterglow, Aachen

ADDRESS OF THE EDITORIAL
Flexible Elektrische Netze FEN GmbH
Campus-Boulevard 79
52074 Aachen
Germany
+49 241 80 22471
info@FENaachen.net
www.FENaachen.net

Note:
Please write to marketing@FENaachen.net, if you like one of the texts in German.