Flexible
Elektrische
Netze

ANNUAL REPORT 2014

Center for FEN

Flexible Elektrische Netze FEN GmbH: Annual Report 2014
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Table of Contents

Annual Report
Welcome

Dear reader

A very interesting but also challenging year has passed and we are looking toward even more ambitious tasks which are lying ahead of us. The 'Energiewende' has brought up new developments in the energy market and forced energy companies to look for new business models. But not only companies are facing an uncertain future also consumers who are already prosumers since more than 15 years.

In this context a new scientific and industry center was founded to meet those challenges. The Center for FEN (Flexible Elektrische Netze) started its activities with building up a Medium Voltage Consortium and gradually expanding its objectives to a Low and High Voltage Consortium. The Center holds individual services for each consortium to meet the demands of the scientific and industry world.

We are excited to define new paths towards a bright horizon for a sustainable energy future.

Yours sincerely

Aachen, May 2015
Dr. Christian Haag, CEO

Welcome Speeches

Marcel Philipp, Lord Mayor of the City of Aachen

„Since the laying of the cornerstone of the Rhineland-Westphalian Technical University in 1865, research in Aachen was always oriented towards solving practical problems of the industry. Hereby in the following 150 years the RWTH accelerated the local structural change from a mining area into a technology region.

With more than 55,000 students and 12,000 employees learning and working at four universities and colleges, Aachen nowadays is the most important science city in North-Rhine Westphalia and a highly attractive location especially for technology-oriented companies and start-ups. And until today, research in Aachen is highly application oriented and very valuable to many international industry partners. And so is the new Research Campus ‚Flexible Electrical Networks' FEN. Fifteen institutes and eleven companies form this collaboration. With their cross-disciplinary research approach on d.c. voltage technology they lay the groundwork for nothing less than the electric grid of the future."

Thomas Rachel, Parliamentary State Secretary at BMBF

„To meet the challenges of Germany's new energy strategy the Federal Ministry of Education and Research (BMBF) launched the ‚Research Campus - a public-private partnership for innovation'. Under this funding initiative, the BMBF is supporting broad-based, long-term cooperation between science and industry, making it possible in particular to conduct intensive work in complex and multi-faceted areas of research.

The ‚Flexible Electrical Networks' (FEN) Forschungscampus fulfils these requirements most aptly and successfully. Fifteen research institutes and eleven companies are working in close cooperation on innovative structural components for direct-current networks. An independent jury has already endorsed the excellent concept of the Campus. The FEN project at RWTH Aachen University received a positive evaluation at the end of the test phase in 2014 so that it can now expect long-term funding of up to two million euros per year from the BMBF for a period of up to fifteen years."

Prof. Dr.-Ing. Ernst M. Schmachtenberg, Rector at RWTH Aachen University

„Since its establishment, RWTH Aachen University endeavors to conduct research and to utilize its innovations for the benefit of the society. As a result, we work closely with industrial partners in order to put knowledge into practice.

FEN makes a significant contribution towards ensuring a feedback of research and innovation. By means of an interlinking between RWTH Aachen University and well-known companies, FEN makes transdisciplinary and application oriented research possible. Thus, it provides a unique platform for the integral development of power grids. It is therefore gratifying that the funding of this project is guaranteed by the Federal Ministry of Research and Education for the next five years. The funds in the amount to € 10 million can be seen as an initial spark for the development of modern power grids."

Motivation

The energy transition – the so-called Energiewende – as decided by the German Federal Government, requires to make structural alterations to the energy supply system. Germany is confronted with economic, technological and societal challenges resulting from the required transformation to renewable electrical energy.

Renewable energy, which is for instance gained from wind or sun, needs be transmitted over large distances to both conurbations and industrial regions with high energy requirements. Furthermore, it needs to be distributed in a flexible manner.

The existing electrical three-phase alternating current (AC) system was designed for a top-down distribution of energy from central power stations. The energy transition requires the transformation of existing electrical infrastructure to integrate a high share of volatile renewable generation.

Electrical grids of the future have to be flexible in order to embed the volatile distributed generation into an overall system. At the same time they have to transmit energy as efficient as possible, even under partial load conditions.

The transdisciplinary research topics of FEN focus on electrical energy and include all voltage levels from low via medium to high-voltage. The central research approach is the development and integration of the direct current (DC) technology into all voltage levels. The use of DC could help making the energy transition more economical than the existing three-phase AC system. DC connections are already the most cost-efficient solution in the case of high-power point-to-point transmission of electrical power over large distance or via undersea cables. Taken as a whole the DC technology has some essential advantages over the currently used alternating voltage:

- Better utilization of cables and wires
- Increased efficiency
- Reduced need of materials

In the Center for FEN the research partners are investigating the suitability of DC for future electrical grids. Possible interfaces between existing and new electrical power supply systems are to ensure compatibility with the existing network infrastructure.

Vision

The aim is to develop electrical grids for a future energy supply which is characterized by a high share of volatile, renewable and decentralized generation. Furthermore, the vision of the Center is to enable a more efficient and flexible transmission and distribution of electrical energy without compromising the recognized high level of security of supply in Germany. Ultimately, it comes to a sustainable, climate-friendly energy supply of the future at affordable costs.

The future electrical grid will be distinguished by great flexibility. On one hand many small sources will supply the electrical grid (small combined heat and power plants as well as solar and wind farms; the current consumer will become a „prosumer“). On the other hand big plants like offshore wind farms or solar farms in rural areas have to be integrated over long transmission paths.

As renewable energy sources rely on the weather their power generation cannot be foreacasted perfectly. Additionally, existing large power plants cannot change their operating point very quickly. These two restrictions require the integration of storage systems and an increased flexibility in grids to integrate a high share of renewable generation in the future.

The diagram shows a model of a future energy supply system. The main features are a mixture of volatile renewable and controllable electrical generation units and a close linkage between the electrical, thermal and gas power systems. The storage of energy in all three grids covers different durations from seconds to days or even weeks.

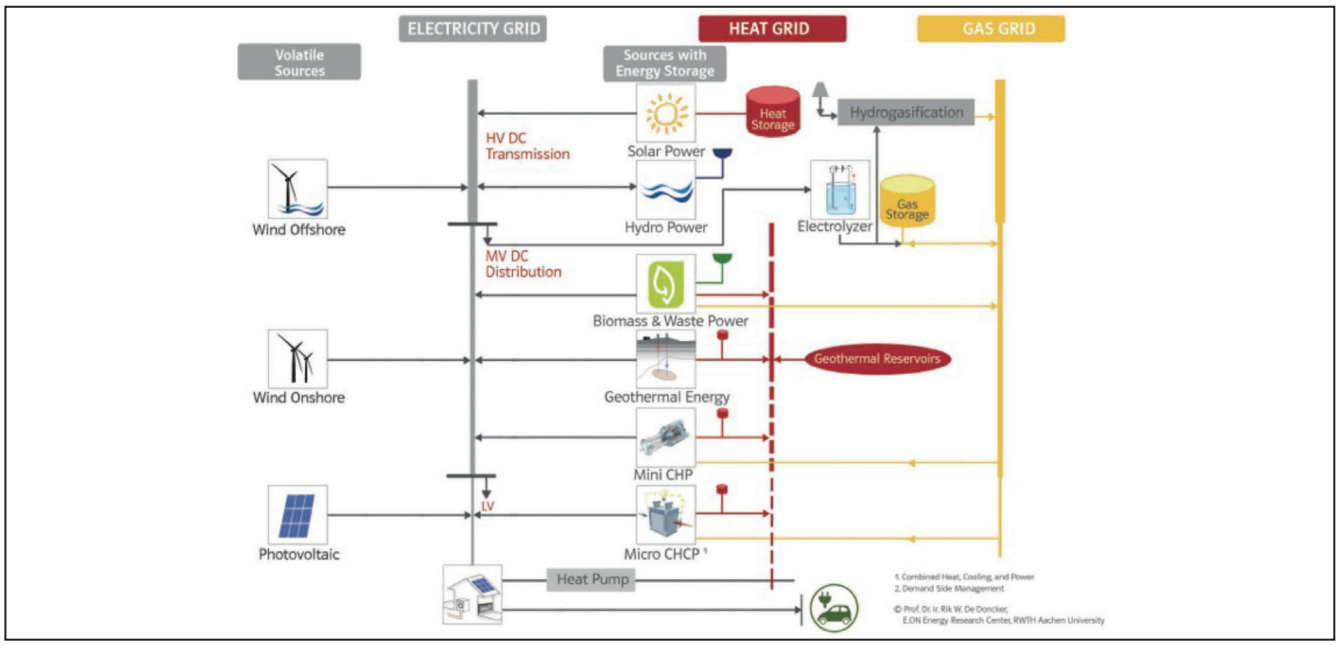

Fig.: Future energy grid with an interconnection between electrical, thermal and gas power systems

Concept

Based on the motivation above, RWTH Aachen University together with industry partners has founded the Center for FEN. To cope with the challenges of the energy transition it is necessary to pool competences and disciplines.

The combination of scientific and industry research allows for an intensive exchange of knowledge. On the one hand the results of scientific research have an immediate influence on products and services of the involved companies, on the other hand these applications are continuously investigated and improved by the scientific institutions.

The Center for FEN which is an association of companies and institutes of the RWTH Aachen University offers both competences. The industry partners belong to all areas of the field of energy supply and cover the entire value chain of the DC technology. The university partners originate in seven faculties. Due to their cooperation it is possible to look at electrical grids in their entirety.

The research activities of the Center for FEN takes place in the Campus at RWTH Aachen University, where the institutes' offices, main laboratories and test-benches are located. This is also the location where the planned medium-voltage DC experimental grid will be installed.

There the FEN GmbH has rented a modern, light-flooded office space, where staff from university and company partners work together on the research projects and also exchange informally. In this so-called FEN Think Tank the staff work in the middle of one of the largest technology-oriented research landscapes in Europe with a unique research infrastructure (see page 34). The office, located on the fifth floor, offers a panoramic view over the RWTH Aachen Campus Melaten. The staff get involved on the campus with their own research, qualified trainees and further education programs.
Furthermore, in the FEN Think Tank each employee has their own workplace and access to a meeting room and a kitchen. In addition, two e-bikes and an e-car are available.

Fig.: Concept of the Center for FEN

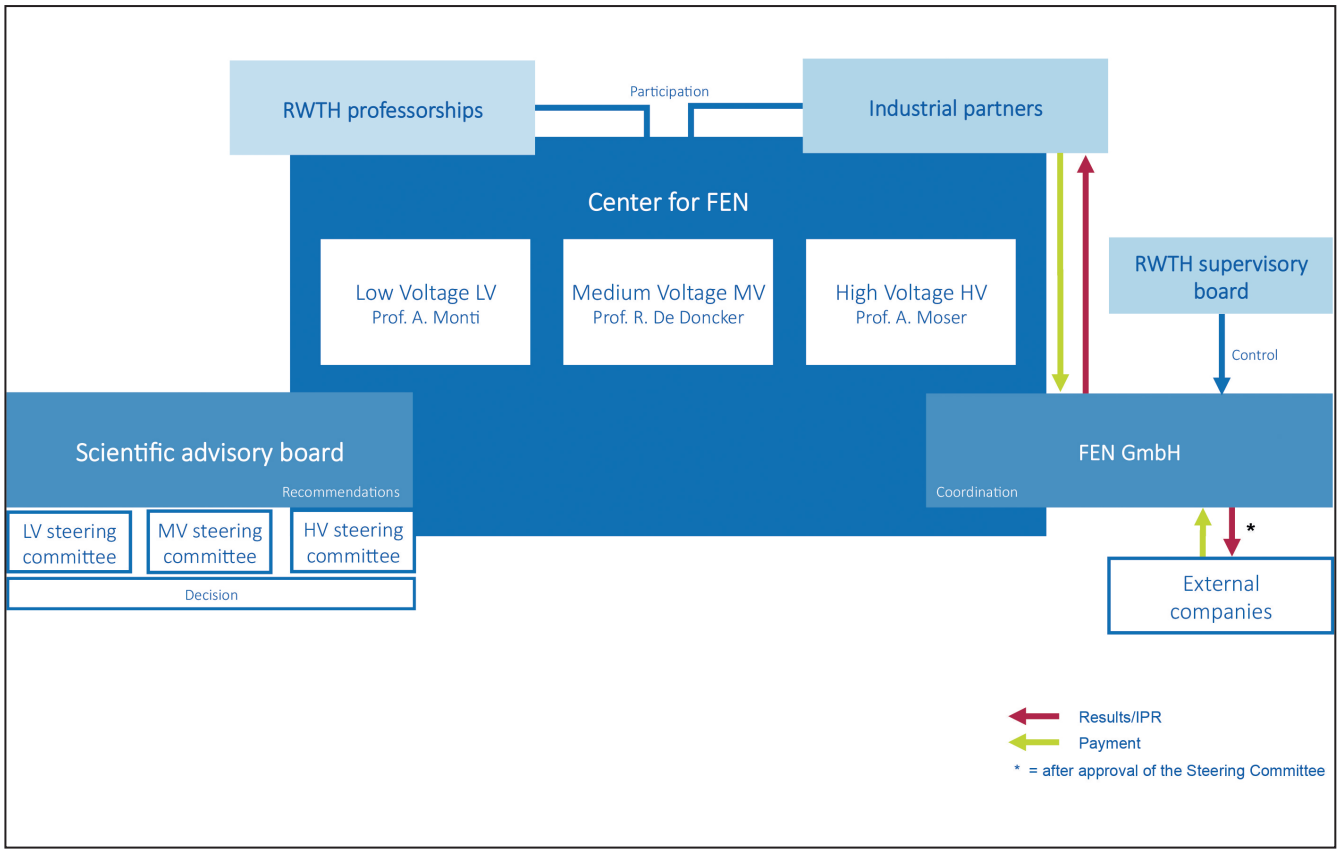

Fig.: Organizational structure of the Center for FEN

Both industry and university partners develop and validate concepts and components within the context of precompetitive research. The Center for FEN will also be active in the development of norms and standards for DC systems. Additionally, bi-lateral, exclusive collaborations between partners to develop commercial products and services are also possible within the Center. Through the close collaboration and joint research in Aachen, the results can quickly be used to accelerate innovation.
Moreover, due to the open membership concept new partners can join the Center for FEN anytime.

The Center for FEN is divided into three consortia: low, medium and high voltage. Each consortium is led by a RWTH professor. This ensures the strategic direction of research in accordance with his area of research at the RWTH Aachen University. The professors are supported by their respective chief engineers in operational implementation.

Each consortium has its own steering committee. It summarizes the industry parties of the respective voltage level. The scientific advisory board, consisting of RWTH professors and company representatives, makes recommendations to the steering committees on research topics, new projects, patents and partners.

The FEN GmbH is responsible for the Center organisation. It also serves as a central contact for the RWTH Aachen University and industrial enterprises. The FEN GmbH is controlled by the supervisory board, consisting of RWTH professors, as well as one member of the RWTH-management and the board of the Forschungszentrum Jülich.

Low Voltage Consortium

New forms of collaboration between industry and academia are on the way. The Low Voltage Consortium allows networking and consensus building between industry participants regarding research and development in the area of power grids of the future on low voltage level, supported by university for the creation of innovation.

The Low Voltage Consortium is subdivided into two communities:

- Software
  (LV Grid Automation / EU Cloud Platform)
- Hardware
  (LV Components & Electronics / Standards)

The industry partners are able to choose between these two communities: They have the opportunity to sign up for both communities or only for one community.

Additionally, there are three corresponding services in the LV-Consortium:

- EU Project Proposal Support
- Technical Seminars and Executive Education
- Lab Infrastructure and DC Experimental Building

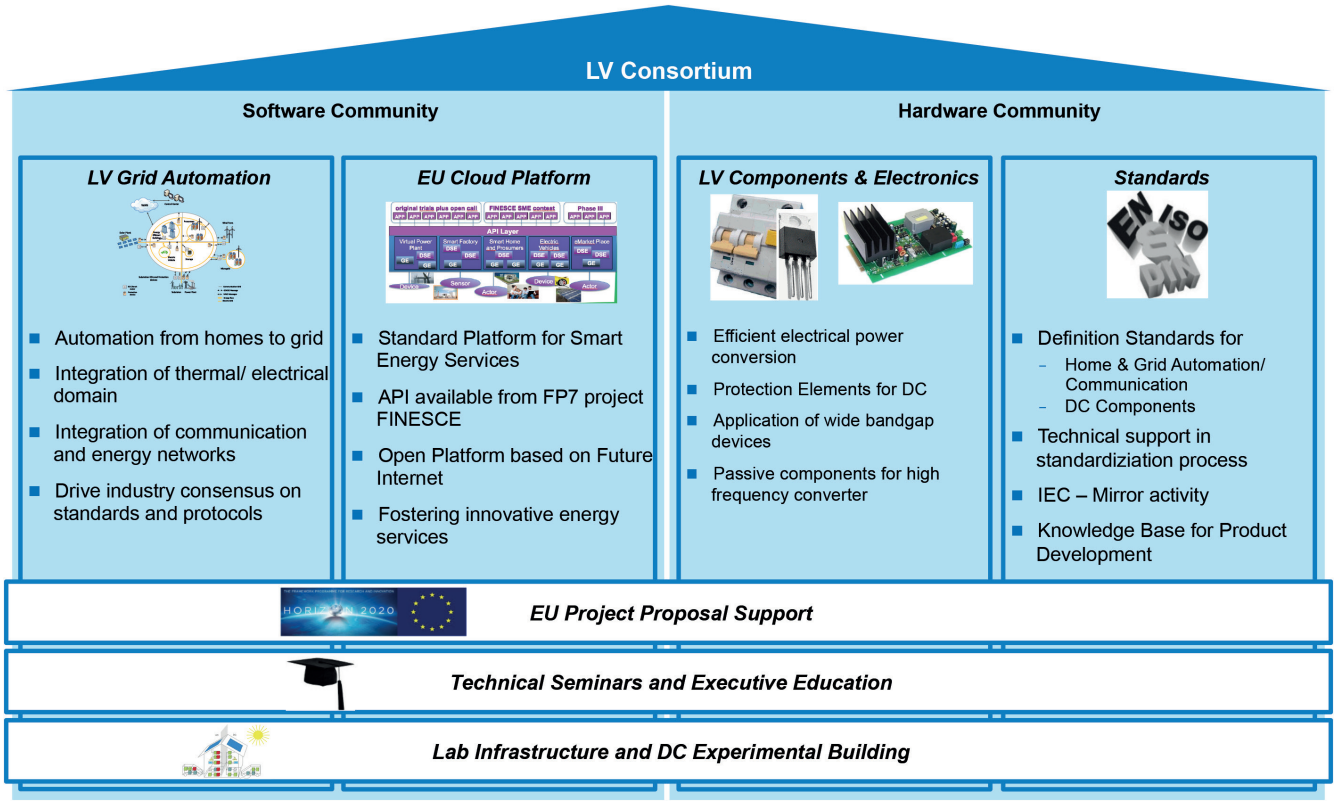

Fig.: Overview of the LV-Consortium

We want to build up the research area low voltage as an European Competence Center for the automation of low voltage.

Prof. Antonello Monti

LV Grid Automation

This group is engaged in grid automation concepts for the integration of building automation. Several services can be defined and developed, e.g.: Storage on demand, Power Quality Support, Voltage Control, Demand-Side Management/Demand Response.

'Grid Automation' also includes the integration of electrical and thermal domains, utilization of flexibilities of different phenomena and realization of synergies between both domains to develop holistic energy solutions. At the same time, future energy networks will benefit from the integration with communication networks. Modern forms of communication enable solutions for smart grids. Furthermore, the group endeavours for developing industry consensus on standards and protocols with the objective to provide interoperability and boost market share of the partners' products.

Distribution grids are nowadays evolving in the direction of Active Distribution Network. There is a clear need of thinking in terms of automation architecture. This group will benefit from the experience of several large EU projects such as IDE4L.

EU Cloud Platform

In this group research and implementation will be performed for a software platform spanning the energy business domain. The idea is to define a standard architecture for software implementation in the cloud. Starting from a lower level of data integration from the field (protocol and data modeling), new services can be developed and implemented.
The benefit of such an approach is the achievement of a high level of software interoperability among the different players.

Such a vision is very much in line with the current evolution of the utilities in Europe that are becoming more and more service-based and customer oriented. The platform is then a pre-competitive effort that will boost the capabilities of modern utilities and offer vendors the possibility to quickly integrate their component in a vision of Internet of Things for Energy.
A first platform implementation as well as an application programming interface is available from the EU FP7 project FINESCE (Future INtErnet Smart Utility ServiCEs). The platform will be shared as an open source version, allowing industrial partners to use this as a basis for development of their dedicated platform implementation.

LV Components and Electronics

Within this research activity the generation of electronic power conversion units are one mayor objective. Those are used in electrical powered equipment like regenerative energy sources, luminaires and supply units for electrical controlled appliances and electrical drives.

By introducing a DC-grid, electrical power conversion efficiencies can be enhanced and component costs could be reduced. To enable economically priced, highly efficient power converter with reduced volume, available concepts must be reviewed and the application of newly available wide-band gap semiconductor devices have to be evaluated. Also supplementary components used in a DC-grid are needed to provide protection functionality.

Standards
Standards of DC-grid component must be defined to ensure the compliance of safety aspects and to provide interoperability. Once standards are defined and accepted, products can be developed and launched in accordance to an international commitment. This community supports the regulation process, which is nationally organized by VDE/DKE.

Historically, the actual electrical AC-distribution grid is well defined, since it exists for more than a century. A DC-grid with identical energy distribution capability compared to an AC-grid has not been realized yet. Thus, no standards are available. Some regulation can be adopted from the AC-grid while others have to be adopted and newly specified.

The standardization will be lead from the German VDE/DKE-Consortium. Together with industry and scientific institutions the regulations will be defined by an iterative process. The group 'Components and Electronics' supports actively the standardization within the DKE-Consortium.

The contribution from FEN to the DKE-Commission is twofold:

1. Standardization Roadmap for low voltage DC-grids:
Within this activity the regulations needed for a DC-grid will be evaluated and a roadmap to setup missing regulations will be established. The regulations will be evaluated subsequently over the following two years.

2. Study on DC-distribution grids:
A study focusing on the implementation of DC-grids will be simultaneously evaluated to the standardization process. Low-voltage and low voltage grids, AC- and DC-grids as well as the combination of both will be analysed.

EU Project Proposal Support
The 'EU Project Proposal Support' will be supervised by a specialist on EU project administration, who provides support for development of proposals between Consortium partners and RWTH institutes. This expert will guide in administrative aspects in order to shape the proposals with the objective of being promising. Furthermore, the search for applicable calls on EU level will also be supported and offered to the partners.

Technical Seminars and Executive Education
Among the tender of RWTH Aachen International Academy, the partner of the LV-Consortium can benefit from special education offers on recent research developments corresponding to low voltage energy concepts. These proposals will be available for consortium partners at privileged rates.

Laboratory Infrastructure and DC-Experimental Building
The laboratory infrastructure of RWTH institutes within the LV-Consortium are available for use in joint projects with consortium partners. The lab infrastructure includes the following components and solutions:

- Real-time Simulation
- RTDS
- OPAL-RT
- DSP Cluster for distributed systems
- Hardware-in-the-Loop Setup
- Power flow tools
- Communication emulation
- Co-simulation
- Power / Communication
- Multi-physics
- Monitoring Platform
- Cloud integration

To demonstrate a DC-grid, components for grid will be implemented to the DC-Experimental Building. Thus, it is possible to demonstrate

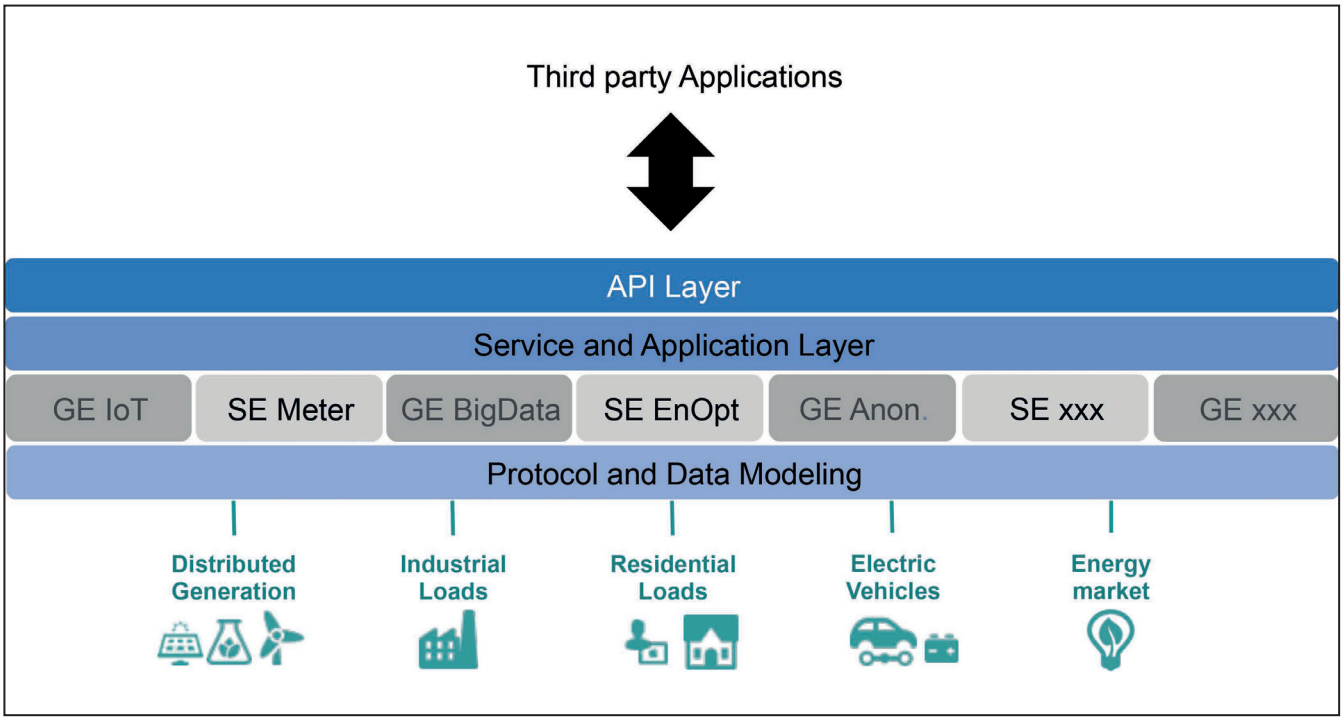

Fig.: Concept of cloud platform for energy services

the function of the individual components and to validate the achievable advantages. Within a planned DC-Experimental Building based on DC-technology, interactions of components as well as control concepts and new electric/thermal systems can be developed and tested.

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Medium Voltage Consortium

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. Already today and more and more increasing in the future small power stations feed electrical energy into the low and medium-voltage distribution grids. All the energy that is not directly used locally will be transmitted through the medium-voltage systems. As much of that power will be generated by volatile sources, grids have to be flexible to receive and distribute the electric energy.

The grid today is meshed only at the transmission level, i.e. the high and very high-voltage level (typically above 100 kV). In contrast, medium and low-voltage AC distribution grids are constructed radial 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. Due to the connection via transformers to the high-voltage grid, different voltage phase angles may occur between sub-stations, leading to high circulating currents when interconnecting AC distribution grids.

One possibility to increase the flexibility in conventional three-phase AC systems is to interconnect grid nodes with DC systems, as illustrated in the figure below. With DC interconnections the voltage phase shifts, as well as the frequency of the different AC nodes are decoupled. The connection of other DC power plants, e.g. a wind park and PV systems, as well as battery storage systems or load centers directly to this DC connection may allow further cost reduction and reliability advantages for the overall system.

On top of the increased flexibility in distribution grids other advantages of DC systems are higher efficiency and less use of materials, especially copper and iron,

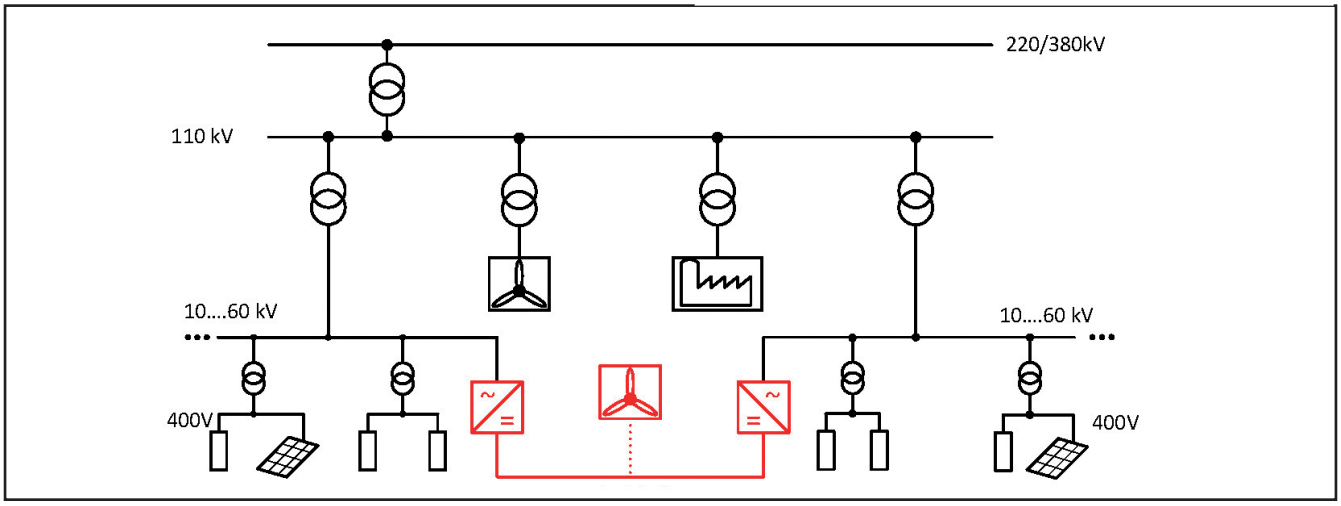

Fig.: DC Connection (colored red) of AC Systems

Medium voltage DC distribution grids offer considerable advantages. We work on solutions, for example for collector fields of offshore-windfarms, as well as meshed distribution grids. To increase efficiency, reduce material usage and to improve flexibility, we develop and demonstrate new power electronic concepts and systems based on DC technologies.

Prof. Rik W. De Doncker

compared to 50 Hz AC systems.
Main goal of the Medium Voltage Consortium is the construction of a Medium-Voltage DC Research Grid on RWTH Aachen Campus. It will connect several high-power test benches of the university with medium-voltage DC cables. At each test bench a DC-DC converter will be installed, connecting the research grid to the DC link of the test bench. With the research grid, electrical components like the converters and cables, but also (hybrid) switch gear for the interruption of DC currents can be tested in the future. Furthermore, different control, operation and protection concepts can be evaluated.

In addition to the research grid three other research projects have been started that focus on planning, component development and control and automation of medium-voltage DC systems, including the interfaces to AC and to high and low-voltage DC systems. Finally, the Medium Voltage Consortium will push the development of norms and standards for medium-voltage DC systems.

The research work of the Medium Voltage Consortium is supported by an initiative of the Federal Ministry of Education and Research (BMBF), which is called “Forschungscampus - a public-private partnership for innovation“. With this funding initiative the BMBF supports universities and companies which are working collaboratively on complex areas of research on a long term basis. It is of vital importance that those areas contain high innovation capabilities and societal relevance.

The proximity on a research campus enables close cooperation between partners from science and industry. This is particularly important in view of the different interests and needs in conducting join research projects. It means that projects are planned from the very beginning to take future applications into account and facilitates the successful implementation of research results in new products, processes and services.

The Forschungscampus FEN is one of nine in Germany. The winners of the funding initiative were announced on 25 September 2012 by the Federal Ministry of Education and Research (BMBF) together with jury chairs Henning Kagermann, President of the German National Academy of Science and Engineering (acatech), and Ernst Rietschel, former president of the Leibniz Association.

The Forschungscampus FEN is supported in the first five year main phase with ten million Euros. For continuing research another twenty million Euros can be granted by the ministry in following phases.

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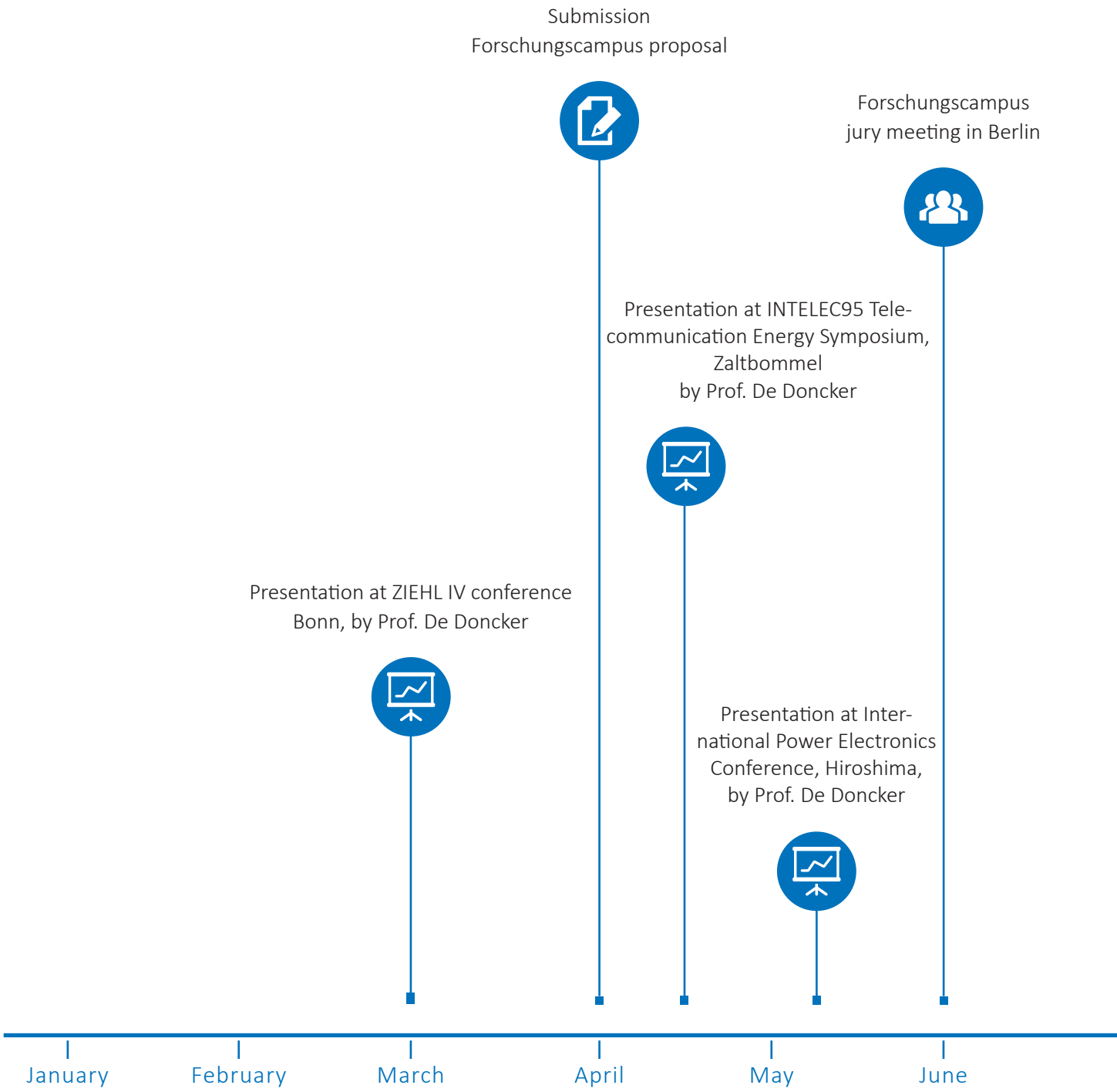
Timeline Medium Voltage Consortium



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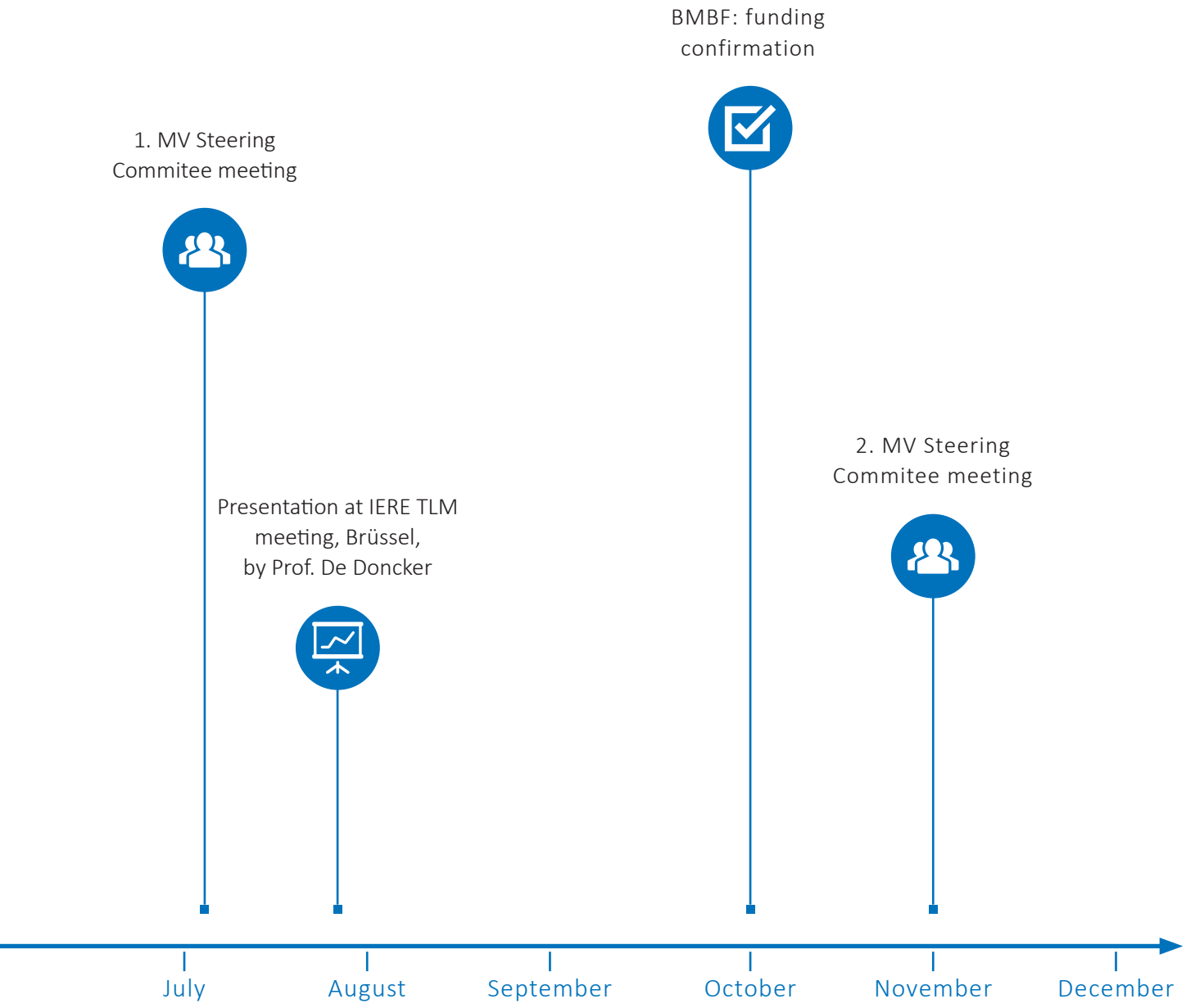
BMBF: funding confirmation
1. MV Steering Commitee meeting
2. MV Steering Commitee meeting
Presentation at IERE TLM meeting, Brüssel, by Prof. De Doncker
July
August
September
October
November
December

High Voltage Consortium

Besides in distribution grids there are also applications for DC technology in overlying high and extra high voltage networks. On the one hand 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 industry 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 the FEN GmbH. In fact there is already an existing consortium, the Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft (FGH) e.V, which is focusing on high and extra high voltage grids for many years. Therefore FEN encourages industry 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 manufactures of equipment for electrical networks.

The history of FGH reaches back almost 100 years, with one of the original aims being support for the introduction of the extra high voltage levels in Germany. From this strong focus on power equipment technology for the 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

There are numerous applications for DC technology in high and extra high voltage grids, yet there is still need for further research especially regarding the impacts on the total system.

Prof. Albert Moser

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 and the development of software solutions for network calculation and evaluation and failure management today are equally important. 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 builds 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.

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Research Projects

Within the Center for FEN research projects are divided into three different groups:

Publicly Funded Projects

Four projects have been defined that are funded with 10 million Euros from 2014 until 2019 by the Federal Ministry of Education and Research (BMBF) within the framework of the Forschungscampus-Initiative. The results of publicly funded projects are published.

1. Modeling, Planning, Conceptual Design and Assessment of Future Grids:

In this project planning and operation guidelines for pure DC and hybrid AC/DC grids as well as protection concepts for DC grids are developed. This project also includes the interdisciplinary consideration of economical, ecological, and societal aspects like the integration of grid components into the landscape and cities as well as technology acceptance and governance. Finally, standardization approaches for components as well as operation principles will be developed.

2. Electrical Equipment and Grid Technologies:

In this project research on components and systems for medium-voltage DC distribution grids is conducted. For example, the partners develop DC-DC converters for voltage conversation and control of load flows including the individual components like power electronic devices and medium-frequency transformers.
Hybrid switches for DC as well as cable systems for the distribution of electrical energy with DC are other topics of research.

3. Control, Operation Systems, Automation:

In this project control and operation as well as energy management concepts will be developed for pure DC and hybrid AC/DC grids. The automation and control systems will be defined, including automation architecture and communication systems. Also a low-power DC grid as generic validation platform will be constructed for the testing of control concepts before they are used in high-power systems.

4. Design, Construction and Testing Campus FEN Research Grid:

In the fourth project a Medium-Voltage DC Research Grid will be designed and built on the campus of RWTH Aachen University. The grid will connect several laboratories, hosting test benches in the megawatt range. Concepts for the control and stability of multi-terminal DC systems as well as components like DC-DC converters can then be tested in the grid in real operating conditions.

Consortium Projects

The Consortium Projects are submitted by RWTH insitutes and industrial partners (MV) and selected through voting at the steering committee meeting. The results of these projects are shared with all partners.

FNP-MV 01: Analysis of possible power supply options from MV DC:

Within this study different concepts for the auxiliary supply of converters and other equipment will be evaluated. The supply will need to provide only a low amount of power, but from a relatively high DC voltage.

FNP-MV 02: Analysis of soft switching with IGBTs:

In this project an up-to-date status of soft switching with IGBTs and the potential of IGBTs in soft-switching applications will be evaluated. An existing test bench at E.ON ERC PGS for the double-pulse test will be modified to also allow soft-switching tests.

FNP-MV 03: MV DC scenarios on DSP Cluster

This project is concerned with the development of MV DC scenarios to be used on an existing DSP cluster. Within the project the library for the DSP cluster will be extended with components like DC-DC converters.

FNP-MV 04: Study on static and transient EMI from hybrid AC/DC MV lines

Findings from existing hybrid AC/DC overhead lines for high-voltage will be analyzed and evaluated for their relevance in medium-voltage scenarios. Within the project both static and transient aspects will be analyzed.

FNP-MV 05: Analysis of required BIL rating in DC Grids with cables

Lightning strikes are a worst-case scenario for electrical systems and components. Therefore this project investigates how the BIL rating could be adapted for respective cable networks. Furthermore, the influence of the higher damping of DC cables in comparison to AC cables will be analyzed.

FNP-MV 06: AC Circuit Breakers in DC Systems:

The interruption of DC is a technical challenge, because at DC no regular zero crossing of the current takes place. This study analyzes the possible use cases of standard AC circuit breakers in DC systems. Especially at the AC link in DC-DC converters standard breakers could be used for the disconnection.

FNP-MV 07: Study on transition from today‘s to future distribution grids:

In this project first scenarios are defined and described, which can serve as a starting point for future distribution grids. Within the study scenarios are distinguished between highly developed countries (e.g. EU, USA) and less developed countries (e.g. India).

Contract research

Furthermore, the Center for FEN offers contract research to his partners. The results are only shared with them.

University Partners

Institute for Automation of Complex Power Systems

The goal of the the *Institute for Automation of Complex Power Systems (ACS)* is to implement a multidisciplinary research approach that is able to capture recent advances in ICT to support the solution of the most advanced problems in the area of grid dynamics and automation. To this end, the research of the ACS is organized around the two main pillars grid operations and ICT for energy. Combining traditional power systems and modern ICT solutions, the ACS conducts research in distributed monitoring and control of power grids, future power grids as cyber-physical infrastructures, and ICT solutions for advanced energy services.

The main topics of research covered for FEN are the automation and control of MVDC grids, including (Power) Hardware-in-the-Loop tests prior to field integration. At the same time, Prof. Monti is leading the FEN Low Voltage (LV) Consortium with focus on LV grid automation and cloud platform for energy.

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Institute for Energy Efficient Building and Indoor Climate

The research of the *Institute for Energy Efficient Buildings and Indoor Climate (EBC)* aims to reduce the energy demand for the creation of thermally comfortable interiors. In addition to the consideration of vehicle interiors, the building is the focus of investigations. The interaction of measures at the building envelope and system technology to increase the energy efficiency of buildings stands in the context of urban energy system with a coupling of thermal and electrical networks. For the development of decentralized energy supply concepts with integration of renewable energy sources concepts of generation, load and storage management are developed.

EBC contributes to FEN in the area of demand side management in buildings and urban neighbourhoods as well as in the coupling between thermal and electrical grid.

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Institute for Future Energy Consumer Needs and Behavior

The *Institute for Future Energy Consumer Needs and Behavior (FCN)* is focused on applied theoretical and empirical research in energy economics, management and policy, with a particular thematic focus on the adoption and diffusion of innovative technologies and on energy consumer needs and behavior.
Economic and management science theory is applied to the sustainable production and use of energy. Research is undertaken both stand-alone and in collaboration with other social, engineering and natural scientists. Explicit consideration of behavioral aspects and motives, attitudes and needs of firms, private households and governments which shape their energy-using behavior is sought for.

The FCN contributes research to FEN in the areas of energy economics, -management, -policy, and-risk management.

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Institute for Power Systems and Power Economics

Research and education at the *Institute for Power Systems and Power Economics (IAEW)* mainly focuses on mathematical simulation, optimization and assessment of technical-economical extension and performance of power systems. This especially applies to power generation and energy markets, energy transmission and energy distribution as well as to gas and heat supply.
The IAEW is split into three research groups: network planning and network operation, power generation and energy markets and system stability and security of supply.

In the context of FEN IAEW is project leader for one of the four BMBF projects and focuses on grid planning and simulation, power economics, reliability of supply as well as systemic impact of DC distribution systems.
Prof. Moser is leading the FEN High Voltage (HV) Consortium.

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Institute of Electrical Machines

The *Institute of Electrical Machines (IEM)* with the chair in electromagnetic energy conversion pursues research in the fields of scientific services for the industry and teaches all aspects of calculation, enhancement and application of electric machines and transducers at the RWTH Aachen. All possible electric machines are being considered such as induction machines, permanent magnetic drives, transverse flux machines, switched reluctance machines and linear drives. The research of the IEM finds application in small-size electric machines with a couple of watts as well as in machines with a high power rating of many megawatts.

The responsibilities of research for FEN include the topics of design and optimization of medium frequency transformers, the characterization of core materials, and enhancements and application of numerical field simulations methods.

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Institute for High Voltage Technology

The main focus concerning research and teaching at the *Institute for High Voltage Technology (IFHT)* lies on components, power equipment and system aspects of a sustainable energy supply. Its broad spectrum of scientific tools includes the development of newly-created systems and methods as well as the evaluation and optimization of established techniques. Mathematical simulations serve as an important tool for research and development, although high priority is placed on the experimental analysis in order to verify the simulation results. The IFHT is divided into four departments: Insulation Systems and Diagnosis, Power System Technologies, Sustainable Distribution Systems and Sustainable Transmission Systems.

The research conducted for FEN includes the topics transmission lines and cable technologies, protection and switch components, insulation coordination, diagnostics and eco balancing.

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Institute for Power Electronics and Electrical Drives

The *Institute for Power Electronics and Electrical Drives (ISEA)* has been working for more than 50 years in the research areas power electronics, power electronic devices, electrical drives and electrochemical energy storage systems.
Besides public founded research projects, ISEA conducts bilateral research and development activities in close cooperation with national and international companies. In addition, ISEA offers engineering services (e.g., measurement/characterization, expert opinion and consulting) for companies.

The research within FEN focuses on power electronic converters and energy storage systems for low-voltage DC grid applications including the research on novel components, targeting at improved efficiency and reduced cost and system volume. Furthermore, the investigations cover regulatory and standardization issues.

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Institute for Power Generation and Storage Systems

The *Institute for Power Generation and Storage Systems (PGS)* provides research and development in MV power-electronic converters and electrical drives and stationary energy storage systems. The field of power electronics is covered thoroughly: from the design and measurement of passive and semiconductor devices to the development and analysis of converter topologies to the design and optimization of converter control. A focus of the institute is the development of MV DC grids and its required components. In addition, the institute conducts research on battery storages and their need in electrical networks.

The contribution of the PGS to FEN is the research of components for future electrical networks. This includes power-electronic devices, medium-frequency transformers and DC-DC converters for future DC substations. When designing and planning the FEN MV DC research grid, PGS brings in its expertise in DC systems. Moreover, PGS provides the infrastructure to analysis and enhance MV components in the megawatt range. Prof. De Doncker is leading the FEN Medium Voltage (MV) Consortium.

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Research Center for Bioelectromagnetic Interaction

As part of the Institute and Out-patient Clinic of Occupational Medicine the ***Research Center for Bioelectromagnetic Interaction (femu)*** is the University Hospital's department of the RWTH Aachen University which conducts interdisciplinary research on biological and medical effects of electric, magnetic, and electromagnetic fields (EMF). It covers scientific information on non-ionizing radiation in its open-access internet information platform (EMF-Portal), which is a tool for risk communication. Additionally, femu carries out active research on possible electromagnetic interference with active implants, such as cardiac pacemakers or defibrillators.

For FEN femu measures electric and magnetic fields emitted by power lines and converter stations and evaluates fields of DC power lines in order to assure compliance with limiting values. Furthermore, it evaluates the current state of knowledge on the possible effects of static fields as well as the possible interference of electronic implants through the occurring fields.

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Institute for Applied Geophysics and Geothermal Energy

The ***Institute for Applied Geophysics and Geothermal Energy (GGE)*** performs research in geophysical reservoir engineering with a special focus on developing geothermal energy as an alternative to diminishing conventional energy resources and on reducing CO2 emissions into the atmosphere. Regarding geothermal energy, our focus is, on the one hand, on regions lacking natural steam reservoirs, on the other hand on super-critical steam reservoirs. In addition, we develop innovative technologies for storing, monitoring, and fixing CO2 injected into geological reservoirs. Finally, we are interested in multi-phase flow and transport in geological reservoirs ranging from the vadose zone to low-permeability hydrocarbon reservoirs.

The contribution to FEN applied or geophysical and hydrodynamic reservoir engineering expertise to problems of heat dissipation from underground power cables.

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HCIC, Textlinguistics and Technial Communication

The Department of *Textlinguistics and Technical Communcation* investigates forms of (computer-aided) communication in companies and public spaces. The research is based on approaches of textlinguistics complemented by approaches of other disciplines (e.g. text technologies) and applied to fields such as professional communication, social media and Enterprise 2.0, communication quality or usability and technology acceptance.

The contribution includes the investigation of the perception of emerging technologies developed by FEN as compared to previously established technologies.

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Institute of Industrial Engineering and Ergonomics

The *Institute of Industrial Engineering and Ergonomics (IAW)* is positioned in the field of design and optimisation of work processes in development, production and services. The focal point of the institute's activities is the employee in the enterprise of the future.

The IAW will investigate the consequences of the DC power grid technology for future occupational profiles and the influence of the technical fundamental projects on existing profiles. As a results of this analysis design recommendations will be developed to adapt the occupational profiles for employees in the field of power supply and to improve in-plant trainings/advanced trainings. Necessary qualifications and skills for the occupation field of power supply will be exploited and the recommendations will be prepared for the training system.

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Institute for Urban Design and Regional Planning

The *Institute for Urban Design and Regional Planning (ISL)* deals with complex urban structures from the regional and overall urban context, on the level of the district up to the interface with architecture.
Based on the historically grown existing context, the focus is on the design and further renovation of sustainable cities and neighborhoods taking into account their technical, environmental, economic and sociocultural conditions.
Topics are the regional differences in demographic and economic developments, the simultaneity of growth and shrinking processes, the change of living and working conditions and infrastructural innovations.

The ISL contributes to FEN with the evaluation of visual impact and tolerance to urban structures.

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Institute of Political Science

The research programme of the *Institute of Political Science (IPW)* covers key areas of political science, in particular political theory, political systems and comparative politics, international relations and political economy. The IPW is also engaged in science, technology and society studies (STS) as well as futures studies.

From an STS perspective it seems particularly instructive to refer to the energy system and power grids (including DC grid technology) as “sociotechnical systems”: systems that are composed of technological infrastructures, products and processes as well as interconnected with networks of institutions, organizations and people. Employing this concept in qualitative social science research within FEN allows to study a technology in-the-making, together with various social, material and temporal dynamics and complexities.

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Institute for Landscape Architecture

The *Institute of Landscape Architecture (LA)* dedicates its teaching and research to the design and development of open spaces in an urban and city regional context. Landscape Architecture is a means to control settlement development and to turn banal landscapes into urban cultural landscapes. The LA provides a broad repertoire of landscape architectural design methods and possibilities on different scales, ranging from an individual building with its direct surrounding, to the quarter with its open spaces to city regions and the strategies of their design.

The institute contributes to FEN with research in the area of the design of energy infrastructure as well as spatial development. With the assumption that DC technology will become an elementally part of a renewable energy system and initiate a growth of regional electric networks the LA will focus three aspects in its work packages: ‚Landscape and DC distribution grids‘, ‚Landscape and small-scale renewable energy systems´ and as an inference of these ‚The potential of landscape development through the DC technology´. These three parts will be examined in two different settings to show the visible and conceptual potentials of the DC technology in shaping different types of landscapes.

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Industry Partners

AixControl

AixControl GmbH is specialized in advanced system solutions for complex power electronics in the low-voltage as well as the medium-voltage range. Established in 2002 as a spin-off of the RWTH Aachen University, AixControl GmbH supports industrial customers on the migration from first functional prototypes into real products.
For this purpose AixControl GmbH has broadly based development departments for power electronics, control and embedded systems including software and firmware development.
In recent years AixControl GmbH built up its production capacities. AixControl GmbH provides customers the whole area of power electronic components from a single source: from development to series production. This enables AixControl to solve Issues during market launch as quick and efficient as possible.

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E.ON

E.ON is an international privately-owned energy supplier which faces fundamental change: through implementing its new strategy, E.ON will in future be focussing entirely on renewables, energy networks and customer solutions, which are the building blocks of the new energy world. The conventional generation, global energy trading and exploration and production businesses segments are being transferred to a new company which will also be listed.
In the 2014 financial year, the staff comprising in excess of more than 58,000 employees based in many countries.
Within the renewables segment, E.ON is one of the world's leading companies. Around 33 million customers purchase gas and electricity from E.ON. The broad electricity generation portfolio comprises around 59 GW of generation capacity. The E.ON Group is run by Group Management in Düsseldorf.

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Fuji Electric

Fuji Electric is an internationally recognised producer of high quality power electronics, electronic devices, as well as energy-, industrial- and social-systems.
Building on technology and experience, Fuji Electric aims to pursue innovation in technology for electric and thermal energy and to continue creating high value-added, environmentally friendly products that use energy with maximum efficiency.
By leveraging the core technologies in circuits, power semiconductors, and control systems, Fuji Electric is able to provide comprehensive energy-creation and conservation platforms.

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GE Energy Power Conversion

GE Energy Power Conversion stands for advanced technology and constant innovation. The engineering company develops and manufactures process control and automation systems, highly efficient power electronics as well as advanced power units and generators and is thereby an established provider of high technology. New technology areas are being explored and developed in collaboration with the research center GE Global Research Europe in Munich.
GE Energy Power Conversion is applying power electronic technology for feeding various grids which are more and more dominated by inverters and less and less by generators. This has a significant impact on the operation and protection of those grids as e.g. the inertia in the grid is reduced or missing. The MV-Consortium is the platform for these future grid topics including DC grids and supports creating standards for multi-vendor interoperability.

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Hager

Hager offers a complete range of products and systems for electrical distribution in industrial and professional buildings as well as the home. These include complete solutions for professional electricians and contractors in the areas of energy distribution, cable management and office or workstation equipment, switches and home automation, as well as safety and security technology such as alarm systems, smoke detectors and motion detectors.

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Hyosung

Hyosung works in a variety of industrial and technology areas that make lifestyle more convenient and more comfortable. Their technology is used for the fibres that make the fabric in clothes, the materials for the tires and seatbelts that keep passengers and cars safe and the power transmission lines that provide electricity. Furthermore Hyosung produces other day-to-day items such as plastic drink bottles, ATM machines, motors, pumps, carpets and plastic wrapping films.
Hyosung is the number one in many business areas in Korea and is looking to expand into additional markets around the world. Their sales and production network consists of over 50 bases that span from Asia to America and Europe, providing convenience to customers in over 130 countries.

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Infineon

With its semiconductor and system solutions for automotive, industry electronics, chip card and security applications *Infineon Technologies AG* offers a response to the three core needs of modern society: energy efficiency, mobility and security. The company is divided into the business segments Automotive, Industrial Power Control, Power Management & Multimarket and Chip Card & Security. Among others in the field of power semiconductors, Infineon is characterized by particular innovation.

Infineon Technologies Bipolar GmbH & Co. KG, a Joint Venture of Infineon AG and Siemens AG, was founded as an independent company in 2007 to focus on future-oriented Bipolar High Power Semiconductors for energy transmission (HVDC) and industrial applications.

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Maschinenfabrik Reinhausen

The core business of *Maschinenfabrik Reinhausen (MR)* is the regulation of power transformers with tap changers. Herein, the company could position itself as a world leader.

Due to the increasing integration of renewable energies in the electricity network, regulation of transformers is of growing importance also at the distribution level. Here the MR also offers innovative system solutions. Worldwide 50 percent of the electric current is flowing through the device of the MR.

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Siemens

The *Siemens Energy Management Division* in Erlangen is one of the leading global suppliers of products, systems, solutions, and services for the economical, reliable and intelligent transmission and distribution of electrical power. As the trusted partner for the development and extension of an efficient and reliable power infrastructure, Energy Management offers utilities and the industry the portfolio they need. This includes facilities and systems for the low-voltage and distribution power grid level, smart grid and energy automation solutions, power supply for industrial plants, and high-voltage transmission systems.
Represented in more than 90 countries, this Siemens Division has nearly 53,000 employees and more than 100 production sites worldwide.

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Schaffner

The *Schaffner Group* is the international leader in the development and production of solutions which ensure the efficient and reliable operation of electronic systems. The range includes EMC components, harmonic filters and magnetic components, as well as the development and implementation of customized solutions.

Components of Schaffner are deployed in energy-efficient drive systems and electronic motor controls, in wind and photovoltaic systems, rail technology, machine tools and robotics, as well as power supplies for numerous electronic devices.

schaffner
energy efficiency and reliability

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Westnetz

Westnetz is an independent distribution system operator for electricity and gas in western Germany. The company ensures a secure energy supply and provides the electricity and gas networks to all market participants on equal terms. Modern processes and innovative operating techniques, coupled with experience of over 100 years of energy supply, characterize Westnetz.

Thereby the company creates the conditions for a safe and efficient network operation and for the design of future „smart“ networks. Westnetz designs the „Energiewende“ in Germany: with the future-oriented extension and conversion of the networks for the intelligent technical infrastructure of tomorrow, with efficient and customer-oriented processes and also with experienced and dedicated staff.

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RWTH Aachen Campus

The Center for FEN is part of the Sustainable Energy Cluster on the RWTH Aachen Campus.

RWTH Aachen University aims to become one of the world's leading technical universities with the RWTH Aachen Campus. With this in mind, up to 19 research clusters with offices, seminar rooms and workshops as well as laboratories and the corresponding infrastructure will be built over the coming years on an area covering approx. 800,000 m².

Industrial enterprises and university institutes will work on defined research foci in an integral and interdisciplinary manner in these research clusters in a new quality of cooperation and exchange. National and international technology firms (research partners) thus have the chance to locate their own research and development capacities on the RWTH Aachen Campus together with university institutes and to get involved in the research and further training activities of RWTH Aachen University – above and beyond individual research cooperations.

The overall RWTH Aachen Campus area covers 2.5 km² and includes the existing RWTH sites as well as two expansion areas – Campus Melaten in the north-west of the city of Aachen and Campus West on part of Aachen Westbahnhof.

Six clusters are currently being realised on Campus Melaten: Smart Logistics, Production Engineering, Photonics, Bio-Medical Engineering, Heavy-Duty Drives as well as Sustainable Energy.

The challenges facing research over the coming years can only be solved by an interdisciplinary approach. Common research problems will be dealt with in an integral and interdisciplinary manner in a cluster. Companies will share resources with university institutes, benefit from synergistic effects and swap know-how

Fig.: Overview of the RWTH Aachen Campus

directly on the spot. This close cooperation will facilitate coordination processes, increase the speed and quality of research results and help cut research and development costs.

RWTH Aachen Campus GmbH was founded specifically to assume the management of the RWTH Aachen Campus. As a joint subsidiary of RWTH Aachen University (95%) and the City of Aachen (5%) it is responsible for the development, realization and safeguarding of the overall Campus concept. The university expansion areas are owned by the Bau- und Liegenschaftsbetrieb NRW (BLB NRW), that is responsible for managing the real estate of the land North Rhine-Westphalia, a total of approx. 4,250 properties with a book value of nine billion euros.

Sustainable Energy Cluster

The main goal of the Sustainable Energy Cluster is to improve energy efficiency and the change to sustainable energy generation. One key strategy that is used here is the integration of different energy networks (electricity, gas, heat) in combination with a local energy generation and supply, which includes today's concept of smart grids (electricity), but goes beyond this.

Not only do resource-friendly forms of energy production have to be examined with regard to energy demand and economic efficiency, social issues also have to be taken into account. With regard to future technologies basic research in various disciplines, e.g. relating to novel thermal insulation materials for use in "intelligent" buildings facades, or new semiconductor structures for utilization in energy conversion technologies (power electronics, phase-change materials) will be conduct.

The cluster pursues an integrative, transdisciplinary and holistic approach which brings together competences from the relevant disciplines and the increasingly imbricated fields of research – a prerequisite for finding intelligent and pragmatic solutions for a sustainable energy future.

The E.ON Energy Research Center (ERC) is the beacon project of the Sustainable Energy Cluster. Its five departments deal with the aforementioned combination of topical energy questions under one roof.

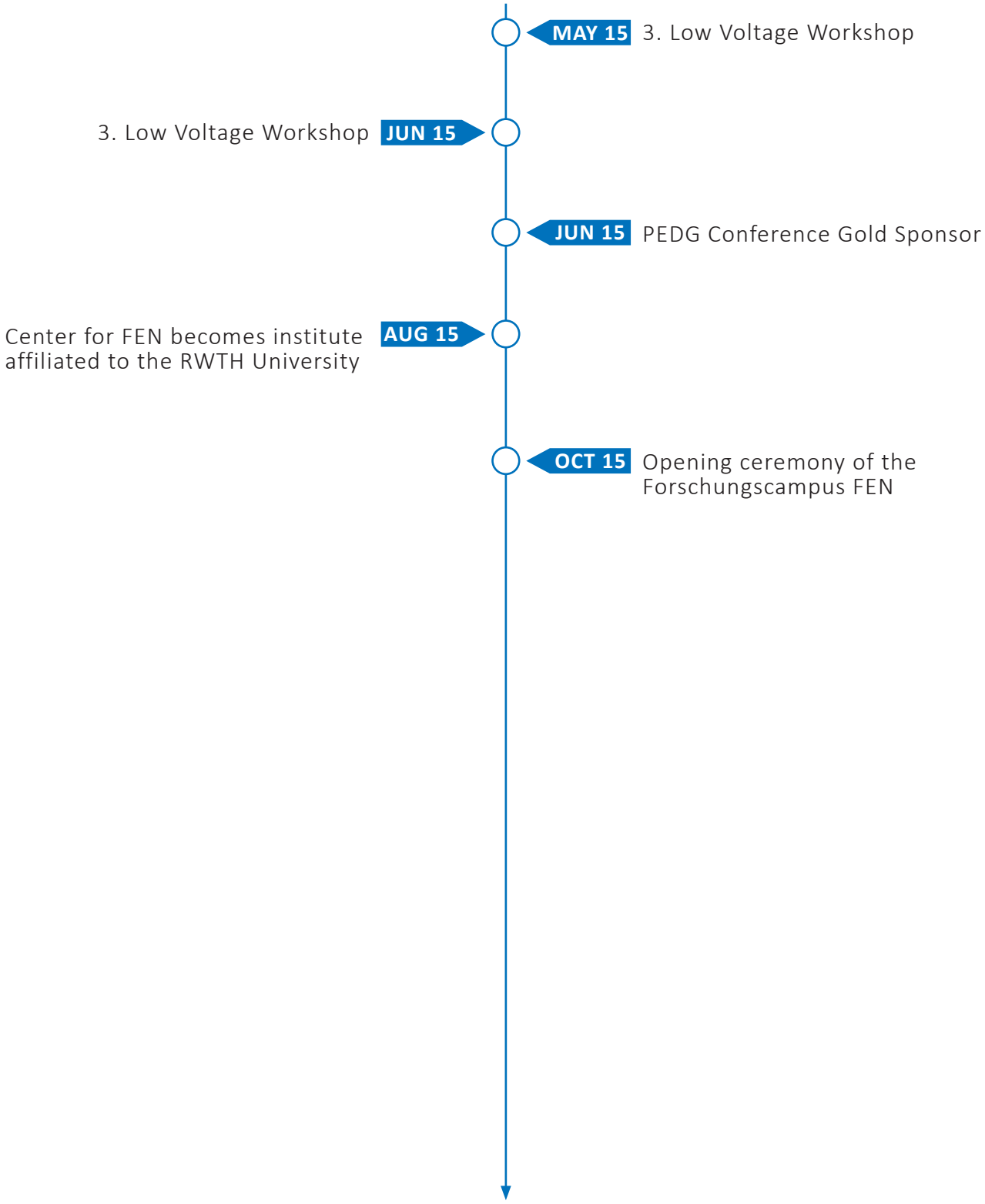
The E.ON Energy Research Center has extensive laboratory equipment such as a five megawatt test lab, real time digital simulation (RTDS), hardware-in-the-loop (HiL), that can be used to investigate questions related to energy-efficient building technology, climatization, smart homes, demand side management and the use of EV as energy stores as well as further interdisciplinary topics that will be researched in close cooperation with the industry.

Fig.: E.ON Energy Research Center

Chronicle

- **JAN 14** 1. Low Voltage Workshop
- **FEB 14** U15/U20 university group Germany/Canada at Aachen
- **MAY 14** Move into Think Tank at Smart Logistics
- **SEP 14** 2. Low Voltage Workshop
- **OCT 14** BMBF funding confirmation
- **NOV 14** Presentation at „5 to 12“ RWTH Science Night, by Dr. Haag
- **NOV 14** Workshop VDE/DKE DC in low-voltage
- **DEC 14** Delivery of two E-Bikes sponsored by RWE
- **DEC 14** Participation at Siemens Center for Knowledge Interchange Conference at Aachen
- **DEC 14** Member of International Energy Cooperation Program (IECP)
- **DEC 14** FEN GmbH uses three electric cars for scientific research

Future


MAY 15
3. Low Voltage Workshop
3. Low Voltage Workshop
JUN 15
JUN 15
PEDG Conference Gold Sponsor
Center for FEN becomes institute affiliated to the RWTH University
AUG 15
OCT 15
Opening ceremony of the Forschungscampus FEN

Facts and Figures

11 Industry Partners

15 RWTH Institutes

260 m² space for FEN Think Tank

Ø18 Researchers working on projects

FACTS

4

PUBLICLY FUNDED

projects have been defined that are funded with 10 million Euros from 2014 until 2019 by the Federal Ministry of Education and Research (BMBF) within the framework of the Forschungscampus-Initiative.

7

CONSORTIUM PROJECTS

have been launched in 2014. The results of these projects belong to the Center for FEN and are shared with all partners.

PROJECTS

19 CONFERENCE PAPERS

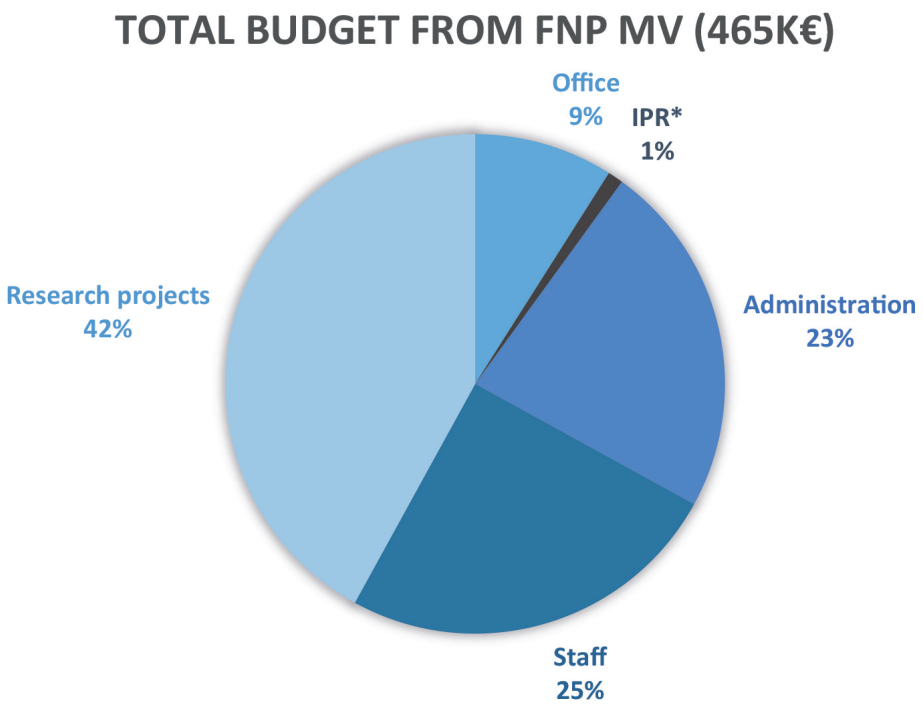
11 JOURNALS

7 DISSERTATIONS

18 B.SC. & M.SC. THESES

10 FURTHER PUBLICATIONS

PUBLICATIONS



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DDM Company: Soft Cover (landscape)
E.ON ERC: Soft Cover (high-voltage transformer), 5, 35
iStock.com/demachi: 17
iStockphoto.com/studiovision: Soft Cover (network)
Peter Winandy: Soft Cover (aerial photograph), 35
photographyByMK/fotolia.com: Soft Cover (high-voltage grid, renewable energy sources)
stockWERK/fotolia.com: Soft Cover (energy transition), 4
rha Aachen: 34
Ute Haupts: 40 (staff)
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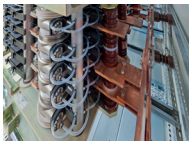



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