Flexible
Elektrische
Netze







ANNUAL REPORT 2015

Center for FEN

Flexible Elektrische Netze FEN GmbH: Annual Report 2015
2nd Edition, 2016

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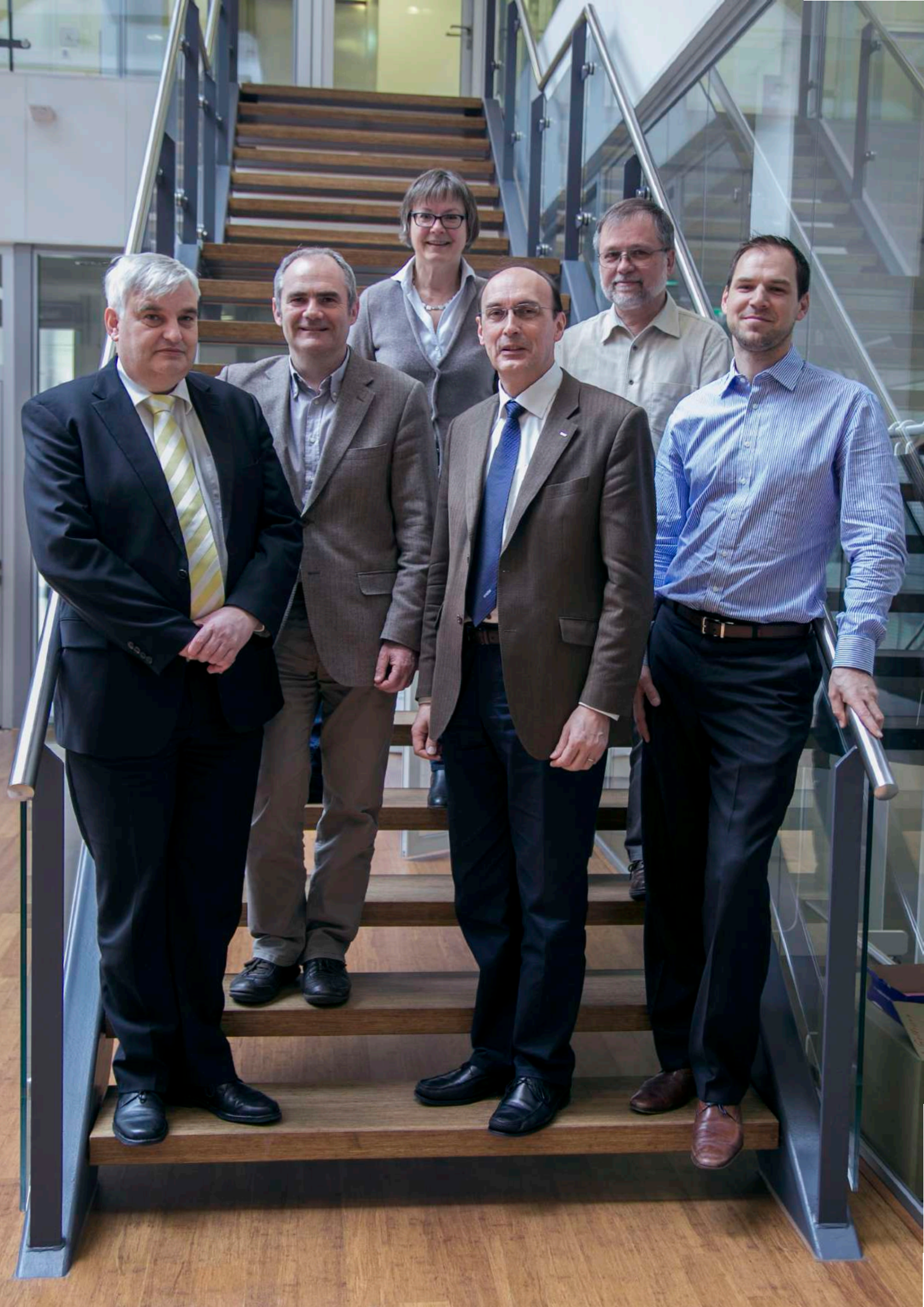


Annual Report
Preface

The year 2015 was another challenging and successful year for FEN. Our Medium Voltage Consortium achieved important results to guarantee a sustainable, reliable and affordable energy supply in the future. Furthermore, the Center for FEN has recently expanded its research activities in the low voltage level. The development of solutions for smart grids are a decisive step towards sustainable energy systems. The FEN Low Voltage Consortium was founded at the end of 2015 with impressive interest from industrial partners. Eight industrial partners have already signed the contract; additional partners are joining in 2016.

We would like to express our gratitude to those whose efforts, work and continuous support provided the foundation for everything we have achieved: our professors of the consortia, our university and industrial partners and our sponsors. Without any and all of these people, none of the developments described in this annual report would have been possible.

We are looking forward to continuing our strong partnership and to completing another series of exciting projects together throughout the coming year.

Sincerely yours,

Prof. Antonello Monti, Ph.D.
Head of LV Consortium
Boardmember FEN GmbH

Prof. Dr. ir. Rik De Doncker
Head of MV Consortium
Boardmember FEN GmbH

Prof. Dr.-Ing. Albert Moser
Head of HV Consortium
Boardmember FEN GmbH

Dr.-Ing. Christian Haag
Managing director FEN GmbH

Photo (from left to right):
Prof. Dr.-Ing. Albert Moser, Prof. Antonello Monti, Ph.D., Prof. Dr. phil. Eva-Maria Jakobs, Prof. Dr. ir. Rik De Doncker, Dr.-Ing. Peter Lürkens, Dr.-Ing. Christian Haag

Welcome Words

Prof. Dr.-Ing. Harald Bolt, Member of the Board of Directors at Forschungszentrum Jülich GmbH

"The Forschungszentrum Jülich GmbH works on solving the scientific and technological challenges associated with the transformation of the German energy system. New approaches in the fields of renewable energy, storage technologies and energy efficiency lead to novel key technologies for Germany's energy strategy. In the Jülich Aachen Research Alliance JARA–Energy almost 50 institutes of RWTH Aachen University and Forschungszentrum Jülich cooperate with their skills, methods and research equipment.

The Research Campus "Flexible Electrical Networks" FEN with the collaboration of fifteen institutes and industrial partners is a center of innovation in the field of DC voltage technologies and for electric grids. The complementary expertise on electrical networks and key technologies for energy applications form the base for a powerful innovation activity for the German ‚Energiewende'."

Helmut Etschenberg, Head of StädteRegion Aachen Authority

"The power supply of the population by means of regionally produced energy raises questions, which can solely be answered by focused and coordinated efforts of experts. The Center for Flexible Electrical Networks (FEN) uniquely brings together scientific and economic experts. Fortunately, not only international leading energy providers, but also regional industrial partners are involved in the Center for FEN. Hence, the economy of the StädteRegion Aachen also benefits from the research activities of FEN. As a regional initiator, FEN creates key innovations in the field of energy and electrical grids. Thus, FEN ensures sustainable growth and employment in the StädteRegion Aachen, which has always been closely connected to power generation due to its mining history.

Furthermore, FEN takes account of climate protection and thereby ensures a sustainable, reliable and affordable energy supply.

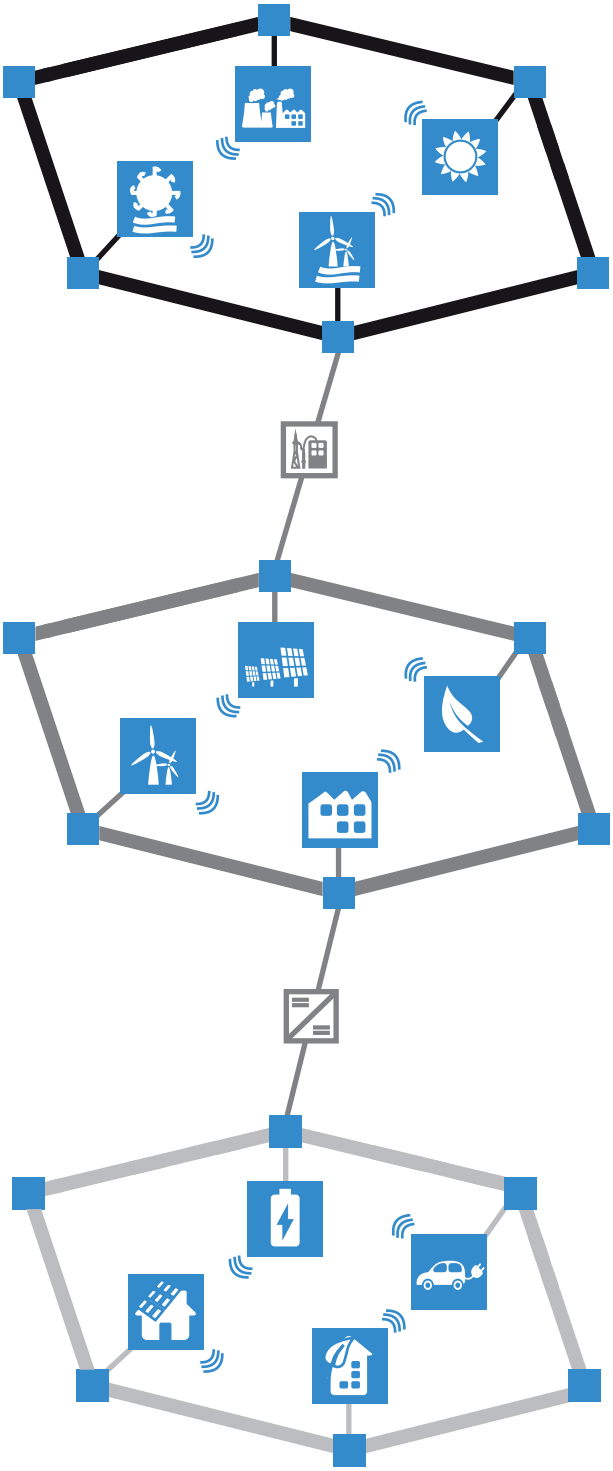
As Städteregionsrat, I am very glad that our region takes on an active role in addressing relevant questions of the future."

Marcelo Masera, Head of Unit "Energy Security, and Market" at Joint Research Centre of the European Commission

"The European electricity system is facing many significant challenges in a political and societal setting that demands the transition towards a low-carbon economy. The need to integrate massive amounts of renewable energy sources and upgrade the electricity infrastructure, while keeping high levels of reliability of service and power quality at an affordable price to consumers, requires adequate answers by all actors: authorities and regulators, utilities and supplies, research and innovation. The Center for FEN embodies the type of innovative, bracing research that is required for confronting this challenge. The Center is exploring new ideas such as DC technologies, it is looking at the whole spectrum from low to high voltage, and it spans from norms and standards to supporting the development of commercial solutions. The combination of academic and industrial partners guarantees the depth and applicability of the results. We at the Joint Research Centre look forward to the outcome of the work at the Center for FEN, and are willing to analyze the implications of that research from the social, economic and policy viewpoints."

Center for Flexible Electrical Networks FEN

Research for the grids of the future



Our Vision

The aim of the Center for Flexible Electrical Networks FEN is to investigate and to develop the flexible power grid in response to the changes of the electrical supply system occurred in recent years. The existing three-phase alternating current (AC) supply system was designed for a top-down distribution from few central power stations. While this was an appropriate solution for the requirements and available technologies from the past, the situation has now fundamentally changed.

Sustainable energy sources and new electronic power conversion technologies have become technically and economically feasible and AC transmission and distribution technology is no longer a must, but an obstacle.

Many decentralized energy sources, like solar systems on roots, produce energy, distributed over the whole country. This means that the formerly exclusive consumer type customer, becomes now a producer. At the same time large scale power generators, like offshore wind farms, have to be connected, sometimes over long distances. Transmission, distribution and storage of electricity need to be more efficient and flexible, so fluctuating and decentralized energy production can be handled easily and economically.

Consequently, this energy reconversion towards CO2 neutral power sources have a strong impact on the required characteristics of the future power grid. Our vision is that it will be ideally implemented by power electronic conversion, being the successor of former 50/60Hz AC technology.

This results into a new kind of electrical grid, which allows flexible interconnection of all consumers and generators and unhindered energy flow by means of DC voltage, rather than AC. This new grid will safeguard the future energy supply with a high share of fluctuating and decentralized renewable energy sources.

Ultimately, the common aim is to achieve a sustainable, reliable and affordable energy supply in the future.

Research focuses

The transdisciplinary research of the Center for FEN concentrates on the integration and development of direct current technology (DC) at all voltage levels (low-, medium- and high-voltage) and on grid solutions for AC and DC grids, leveraging on communication technology, cloud services, integration of energy storage and societal aspects.

The DC technology is not yet established as a standard technology in the electrical power supply system, but its high potential has already been widely recognized.

The use of DC is an enabler to make the future energy supply system more economical than a system based on AC, because of its superior properties in handling distributed and fluctuating power generation. Indeed, DC connections are already one of the most cost-efficient solution in cases of high-power long-distance point-to-point transmission of electricity.

The objective of the Center for FEN is now to achieve and demonstrate the feasibility of DC as a standard solution for future electrical grids.

page 12 ff.
research projects of the LV Consortium

page 24 ff.
research projects of the MV Consortium

Within the Center for FEN there are four different types of research projects: Publicly funded, seed-fund, boost-fund projects and contract research.

Seed-Fund Projects

- Project proposals from industrial partners and RWTH institutes
- Selected through voting at steering-committee meeting
- Results are shared with all partners of the voltage level

Boost-Fund Projects

- Project proposals from industrial partners
- Project budget exceeds seed-fund project
- Additional money invested through industrial partners
- Results are shared with all partners of the voltage level

Concept

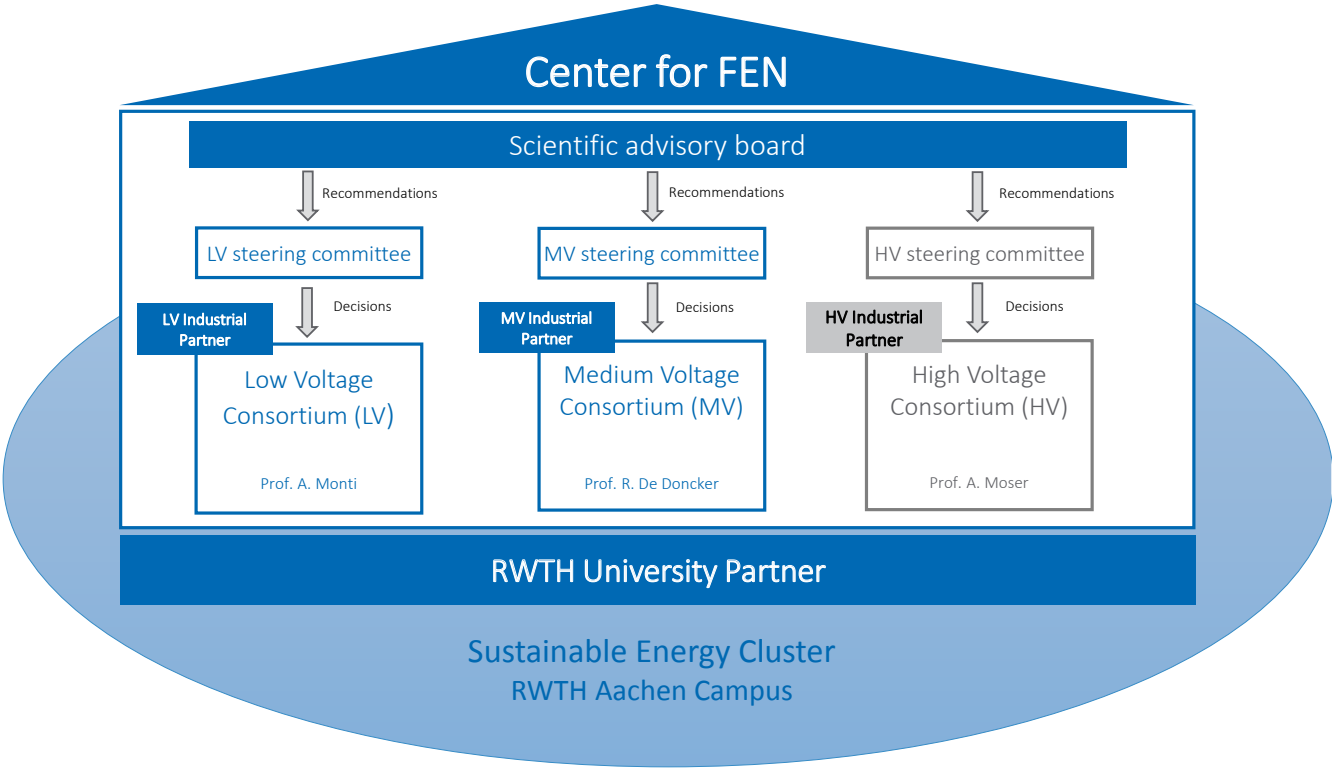
The Center for FEN is an association of institutes of the RWTH Aachen University and three industrial consortia, with the objective to research and develop future electrical grids, designed for the integration of distributed sustainable energy sources.

The approach of the Center for FEN is to combine a wide range of research disciplines and industrial branches, which enable a holistic approach to all aspects of future electrical utility networks.

The joint research of academia and industry under one roof at the Center for FEN facilitates an efficient exchange of knowledge between the partners. In order 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.

The Center for FEN is organized into three consortia associated with the main voltage levels (low, medium, high voltage) in the electrical utility grid. Each consortium is headed by a professor of the RWTH Aachen University and is supported by a Chief Scientific Officer / Program Manager assigned to the consortium.

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



Organizational structure Center for FEN

Anyone who wants to modify the grids of the future needs strong and competent fellows, like the University and Industrial Partners of FEN. The best way to make our future energy supply reliable, affordable and sustainable is to create it yourself.

Dr. Christian Haag

and making decisions. During the meetings, the university partners present their current research status to the industrial partners and together they discuss the next steps. Besides, the industrial partners decide on new seed- and boost-fund projects and take decisions on IP as well as on the admission of new research partners.

An open partnership model allows interested companies to join at any time:

page 16
Become a partner in the LV Consortium

page 30
Become a partner in the MV Consortium

In addition to the steering committees, a scientific advisory board (SAB) is composed of the leaders of the three consortia and elected industrial partners. The SAB meets also four times a year and gives recommendations to the steering committees concerning research projects, research roadmaps and the acquisition of patents.

The FEN GmbH is the operator of the Center for FEN and provides the operative environment of the Center, like office space, project support, IT services, public relations, meetings and workshops. It is also the central contact for the RWTH Aachen University and for industrial enterprises. The FEN GmbH is controlled by the supervisory board, constituted from the Rector of RWTH Aachen University (chair), a board member of Forschungszentrum Jülich and three professors of RWTH Aachen University (proprietors).

Location

The research activities of the Center for FEN are located amid the RWTH Aachen Campus (see page 38/39). The “FEN Think Tank” facilitates the direct exchange of knowledge between the partners.

FEN Think Tank

There, each expert has an own workplace in a modern, light-flooded office space, in which university researchers and company partners work immediately together.

FEN Electric-Vehicle

The office, located on the fifth floor, offers a panoramic view over the RWTH Aachen Campus Melaten. E-bikes and an e-cars allow to move around the campus easily and quickly, e.g. for reaching test facilities at university institutes.
The RWTH Aachen Campus is also the location where the planned Medium Voltage DC Research Grid will be built.

Partner Benefits

Community

- Transdisciplinary team of experts
- Direct exchange of knowledge between science and industry
- FEN symposia, steering committee meetings
- Adminstrative support for EU funded projects
- Access to junior researchers

Training

- Training opportunities at RWTH Aachen International Acadamy
- PhD lectures at RWTH Aachen University
- Events, conferences, seminars and workshops
- Internal workshops and colloquiums

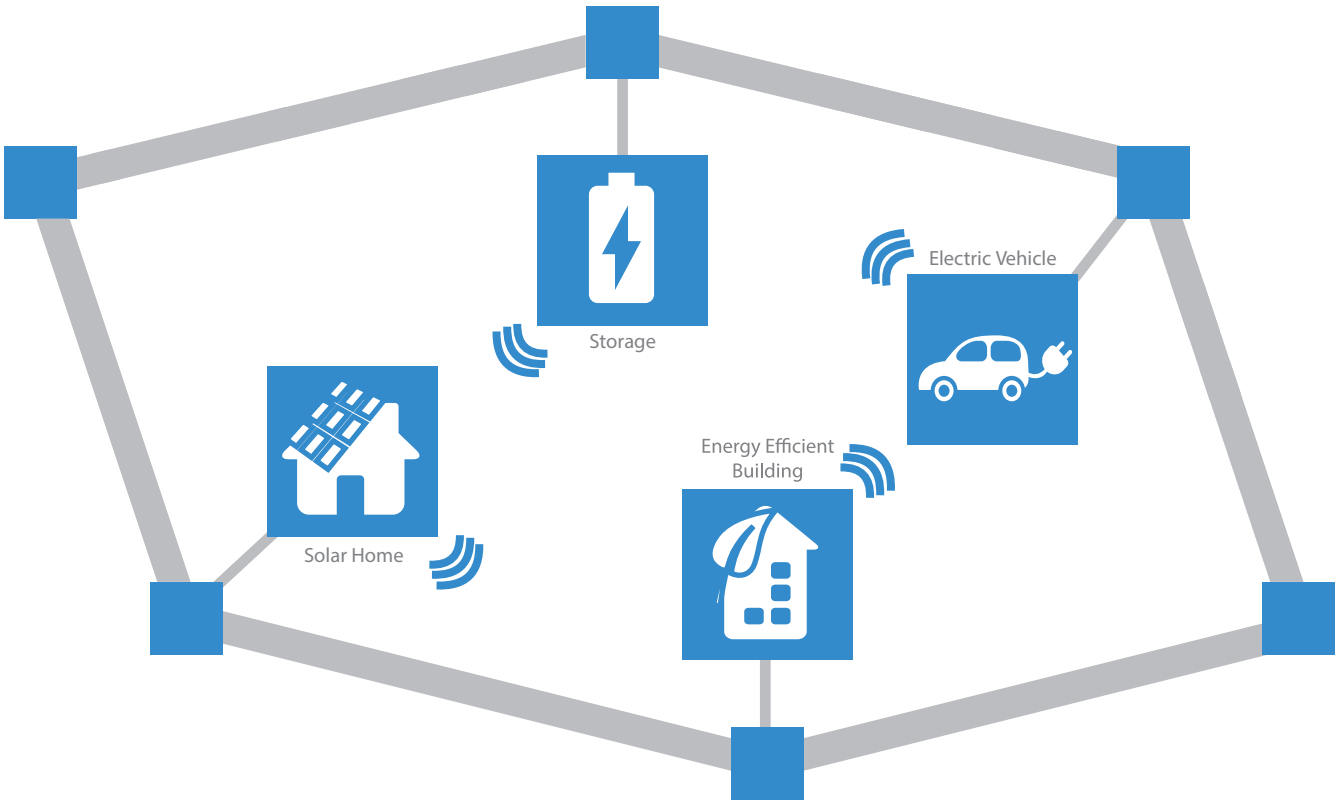
Infrastructure

- 260m² open, modern office space: “FEN Think Tank“
- The Think Tank is in one of the largest technology-oriented research landscapes in Europe: RWTH Aachen Campus
- Access to the laboratory infrastructure of the RWTH institutes
- DC experimental building and MVDC research grid

Research

- Application-oriented, pre-competitive and transdisciplinary research
- Publicly funded projects (BMBF, BMWi, EU etc.) and projects based on the partners‘ ideas
- Access to studies as well as theses and further professional publications
- Use of registered patents
- Contract research framework

Low Voltage Consortium



Low Voltage Consortium

The Low Voltage (LV) Consortium was just founded with impressive interest from industrial partners. Eight industrial partners have already signed the contract; additional partners will participate in 2016.

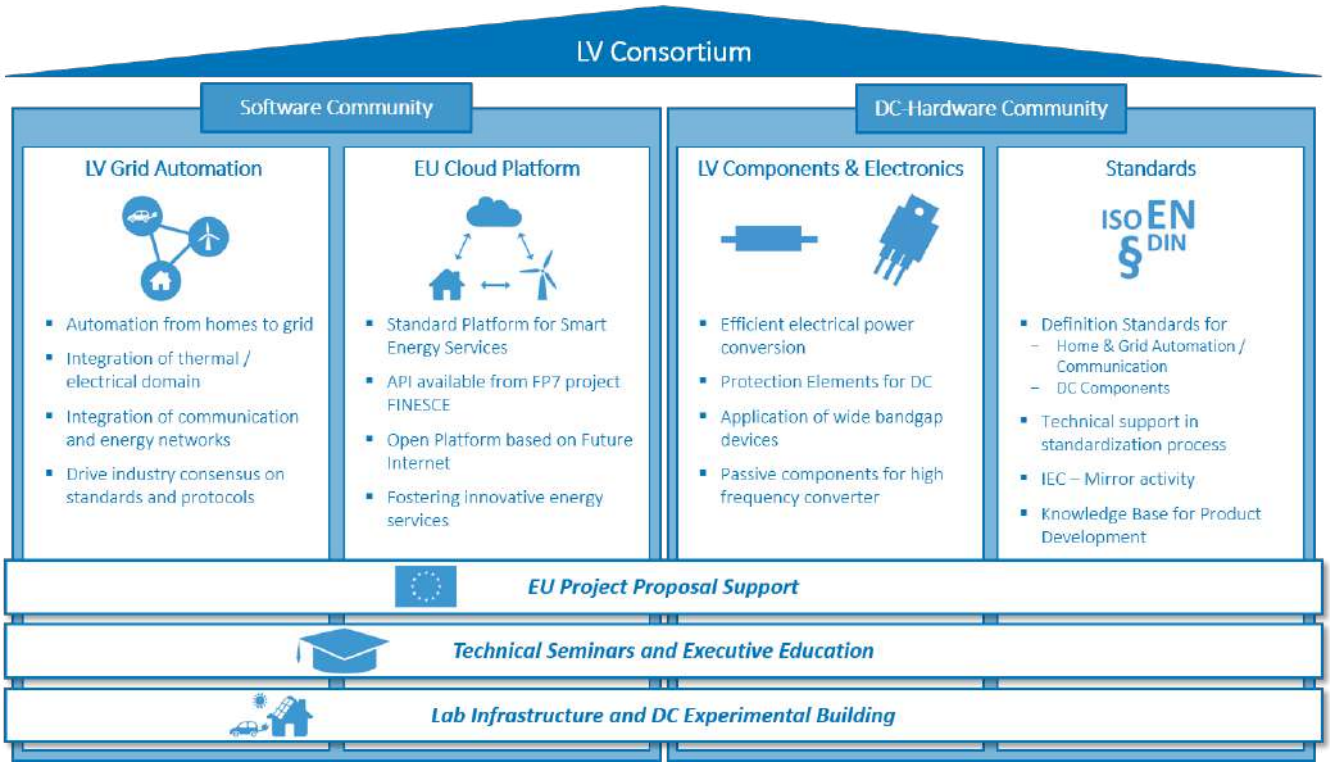
The LV Consortium tackles the grid automation, services, components and standards at low voltage level.

The aim of research in this consortium is the optimal electrical power supply and distribution on low voltage level. New automation concepts and architectures in AC and DC grids and buildings, integration of electrical-thermal-communication domains and the use of DC technology are being applied to support the integration of renewable energy sources.

The LV Consortium is organized into two communities: Software and DC-Hardware, with complementary foci on different research topics.

The Software Community addresses Automation of the LV Grid and development of the service oriented EU Cloud Platform.

The DC-Hardware Community is engaged in LV components & electronics and related standards. Industrial partners can sign up for both communities or only for one community.



Overview of the LV Consortium

The platform from the EU FP7 project FINESCE will be used and further developed in the FEN Low Voltage Consortium. So in the LV Consortium companies are on their way to define requirements for the future software that we expect to drive the energy system.

Prof. Antonello Monti

Software Community

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 and of the related flexibility. 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 Software Community endeavours 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 LV Software Community will further develop this platform.

DC-Hardware Community

The activities on LV components and electronics focus on power electronic voltage transformers, protection components, cable and connectors for grids on low voltage level. Electronic voltage transformers are used in lamps, regenerative energy sources and power supply units for electrical consumers.

To enable economically priced, highly efficient voltage transformers with reduced volumes 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 establishment 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. Thus, the DC grid is not fully specified by standards. 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 oscillating weight of the rotating generators, but the control dynamics of the electronic DC-DC converters. These aspects have to be defined in the context of standardization. First, the regulation needed for a DC grid will be evaluated and a roadmap to setup missing regulations will be established. The standards will be evaluated subsequently over the following two years.

In addition, two seed-fund projects already started with institutes of RWTH Aachen University and more project proposals are under

consideration. The focus of the started projects is on the mapping of a well-developed automation architecture for distribution onto the cloud and on hardware structure and protection concepts.

Additionally, there are three services available to members in the LV Consortium:

EU Project Proposal Support
Since November 2015 a new EU Office is active at the FEN GmbH. Purpose of this office is to offer the members of the LV Consortium dedicated support for the preparation and submission of European project proposals for project consortia composed of FEN industrial partners and RWTH institutes.

The EU Project Proposal support is supervised by a specialist on EU project administration, who first advises the consortium partners on relevant calls on EU level, especially in the framework of the Horizon 2020 Programme, and informs them about further EU initiatives and support networks for companies.

Then this expert assists the partners in the preparation of the proposals, guides them through all administrative aspects of the application process, and supports them in the management of funded EU projects.

Currently, the EU Project Proposal Support is a service included in the LV Partnership. Members of the MV Consortium can benefit from the service upon a payment of an additional fee.

Technical Seminars and Executive Education
The partners of the LV Consortium can benefit from special education offers on cutting edge concepts in low voltage energy, in the framework of the RWTH Aachen International Academy. These services will be available for consortium partners at privileged rates.

Lab Infrastructure and DC Experimental Building
The laboratory infrastructure facilities of the 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:
Thematic focus Software:

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

Thematic focus Components & Electronics:

- Power electronic converter synthesis and characterization
- Battery storage: material, cell and pack characterization

Dr. rer. nat. Marina Maicu, Head of EU Office

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- Characterization of electrical drives
- Electromagnetic compatibility (EMC)
- Device characterization (power semiconductors, magnetic devices and capacitors)
- Reliability and lifetime analysis

For demonstration purposes, DC components will be implemented into a planned low voltage experimental building on the research campus in Jülich. Thus, it is possible to demonstrate the function and interactions of the individual components and to validate the achievable advantages by DC technology.

Furthermore, the FEN GmbH participates on behalf of the LV Consortium in the BMWi project FlAixEnergy with the work packages “conception of local production clusters” and “conceptual design and development of solutions for power distribution”. The aims are to develop a method for the automatic clustering of different production units taking advantage of bundling effects as well as to determine the flexibility that can be offered on the FlAixEnergy platform.

FLAIXENERGY

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

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LV Partnership Model

The LV Partnership Model includes several services and benefits for its partners. It offers different partnership options: SME-Partner and Partner. An open partnership model allows interested companies to join in at any time.

Services & benefits	**SME-Partner**	**Partner**
Votes within the Steering Committee	1	2
Dedicated support for EU-funded research projects	✓	✓
Competence network and platform for Smart Energy Services	✓	✓
Invitation to Annual LV-Symposium	✓	✓
Access to FEN-publications*	✓	✓
Usage of technical infrastructure / conference rooms	(✓)	(✓)
Possibility of renting own office space	✓	✓
Cooperation duration [*years*]	2	2
Annual costs	**10.000 €**	**20.000 €**

✓ included

(✓) fee-based

* Final reports, studies, PhD-thesis; if available bilingual (German/English)

New Industrial Partners - LV Consortium

B.A.U.M Consult

B.A.U.M Consult GmbH supports enterprises, municipalities, regions and governmental institutions throughout Germany and abroad with consultancy on sustainable development. B.A.U.M. understands its role as a link between research, development, production and marketing of sustainable products and services.
B.A.U.M. manages research and development programs and organises conferences and experience exchange events. It helps governments in the application process for EU and worldwide funding and with coordinating huge projects. In international projects, scientific studies and regional development B.A.U.M. concentrates on fostering usage of local renewable energy sources and sustainable mobility patterns. B.A.U.M. supports enterprises to develop sustainable and environment friendly products, helps enterprises and municipalities to establish environmental and sustainability management like ISO 14001 or EMAS.

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Bouygues Energies & Services

Bouygues Energies & Services - a subsidiary of Bouygues Construction – is an expert in energy performance, digital technologies and services. Every day, Bouygues Energies & Services installs, maintains and operates technical systems and provides bespoke services. Bouygues Energie & Services helps their clients and customers by creating an efficient and pleasant working environment, helping manage their energy needs and providing safe, resilient and efficient solutions through leveraging our expertise across our core activities: Energy and digital network; Electrical, thermal and mechanical engineering; and Facility Management (FM). Bouygues Energies & Services commits to long-term performance on:

- Reliable, sustainable infrastructure
- Better connected, safe cities and towns
- Smart, efficient and comfortable buildings including a wide range of FM services
- High-performance industrial processes for greater competitiveness

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ESA Elektroschaltanlagen Grimma

Since 2002, administration, engineering, production, research and development as well as the service centre have been bundled at one site in Grimma. *ESA* produces on a production area of 7,500 sqm using our own CAD-based switchgear and copper machining centre. Naturally, ESA works on the basis of the quality management system according to DIN ISO 9001:2008 and SCC.

Services:

- Engineering
- Planning
- Assembly and commissioning
- Service and trainings
- Research and development

Business segments:

- Low-voltage switchgears
- Medium-voltage switchgears
- Complete power supply for medical locations
- Point heating systems and switchgears for railway
- Automation technology & robotics

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Hager Group

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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Infrastructure technics

Infrastructure technics meets the demanding challenges of automation technology - from concept development to the "turnkey system" – as a contractor or cooperating partner. The company is a technical partner for electrical technology, power distribution and control software.
Regardless of which factors play the most important role in customer projects and which national and international standards and safety guidelines apply – infrastructure technics supports its customers with its industry know-how, experience in research and development and the knowledge the company has acquired in numerous infrastructure projects.
The services in this segment range from the documentation of existing structures to the installation of complete new electrical engineering systems for energy and water suppliers. Clients in the fields of science and business value its research and development know-how as it applies to feasibility, compliance with standards and actual realization.

infrastructure-technics
Engineering Services

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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.

SIEMENS

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Sprint Capital

Sprint Capital Japan was established in Tokyo in 1996 as a financial risk management and service company, which in 2000 started to focus on energy industry. It supported Japanese utilities' electricity trading and risk management in 2002 in face of opening of Japan Electric Power Exchange in 2004. The company expanded industry support from wholesale energy trading to distribution system optimization using smart technology in 2005. It also launched Sprint Capital NW Inc in Portland, Oregon in 2004. After Fukushima nuclear accident in 2011, Sprint Capital provided advisory and consulting services to develop Japan's new electricity and gas market models, with the government, power and gas utilities, industry associations and international energy service providers.
In late 2015, Sprint Capital was elected as the only consulting firm among members of the Government's LNG Market Study Committee until March 2016.

Sprint Capital

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Vacuumschmelze

VACUUMSCHMELZE GmbH & Co. KG is a leading global manufacturer of advanced magnetic materials and related products. In 1914, the first vacuum melting furnace laid the foundation for today's VACUUMSCHMELZE. Then in 1923, melting alloys in a vacuum went into production on an industrial scale. This initial operation was located in Hanau, Germany and later grew into a company that operates on a worldwide basis with 4.400 employees, in more than 50 countries and with annual sales of about approx. 400 million Euro.
Today, VACUUMSCHMELZE's range of products comprises a broad array of advanced semi-finished materials and parts, inductive components for the electronics, magnets and magnet assemblies for use in a wide variety of fields and industries spanning watch-making and medical technology, renewable energies, shipbuilding, automotive and aviation. The use of VACUUMSCHMELZE products is so extensive that we all use them every day - without knowing it.

VAC® VACUUMSCHMELZE

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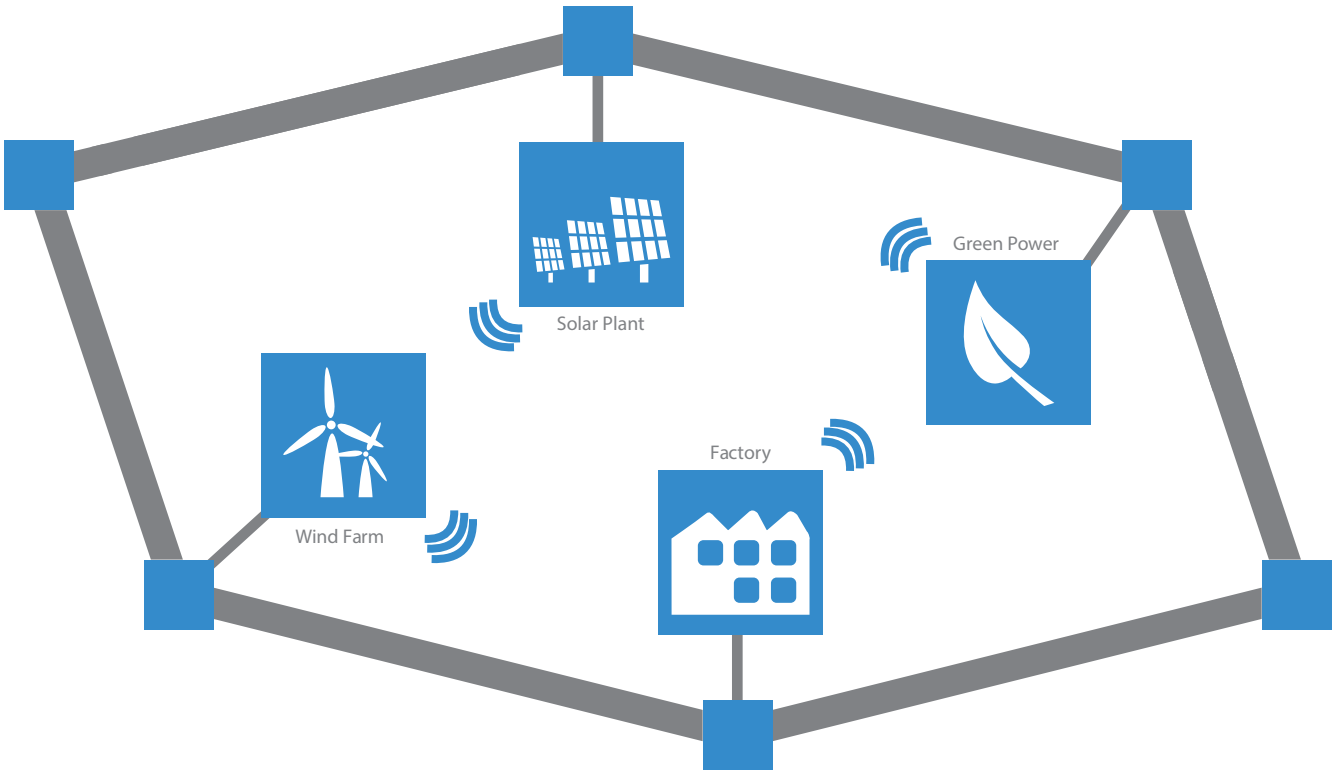
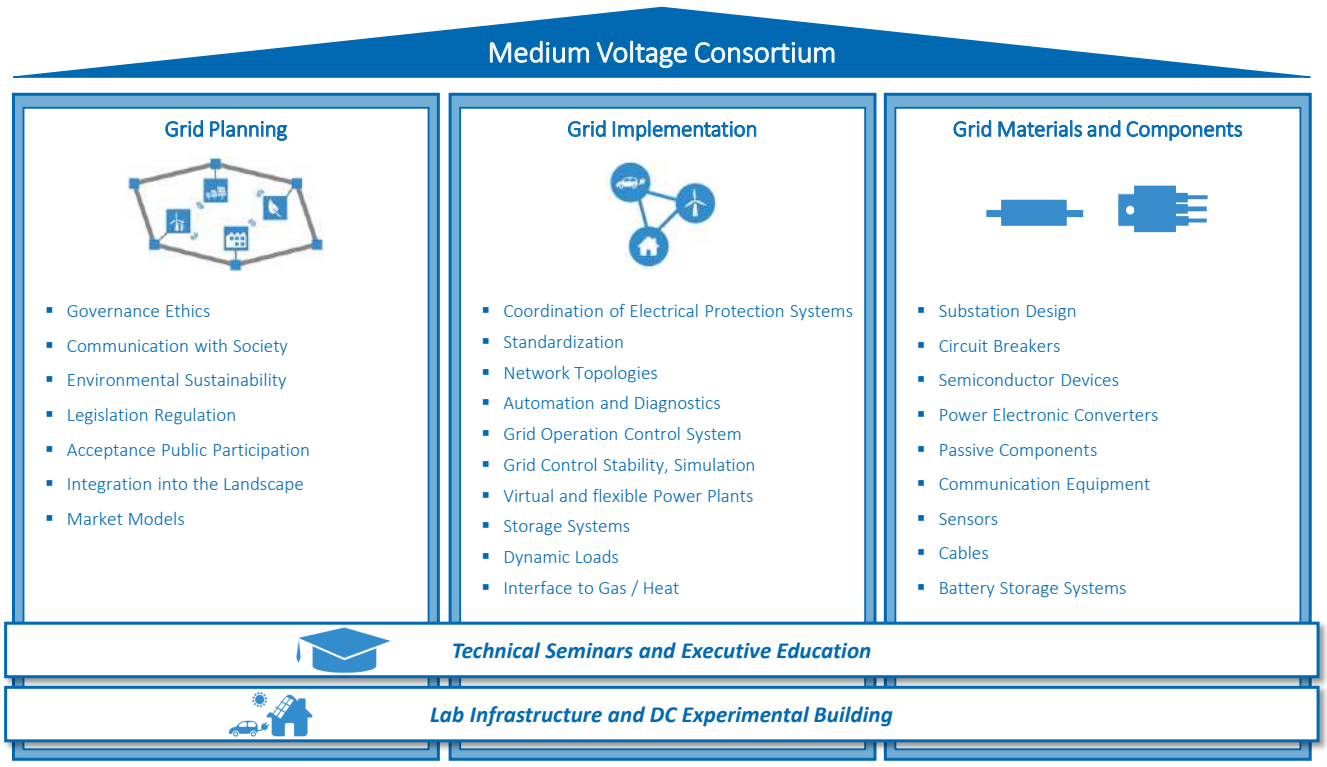
Medium Voltage Consortium



Medium Voltage Consortium

In the MV Consortium the capability of DC technology within the medium voltage level, including the interfaces to AC systems as well as to high and low voltage levels, is analysed. Cable connections, solutions for network automation,-control and-stability, as well as other necessary components for a flexible distribution of the energy are topics of research. The main objective of the consortium is the construction of a Medium Voltage DC Research Grid at the RWTH Aachen Campus Melaten, where various test benches in the megawatt range from different institutes will be connected. The experts carry out field tests on electrical components, such as cables and DC-DC converters, but also (hybrid) switchgears. Furthermore, different control, operation and protection concepts will be evaluated.

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 only at the transmission level, i.e. the high and very high voltage level (typically about 100 kV). 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



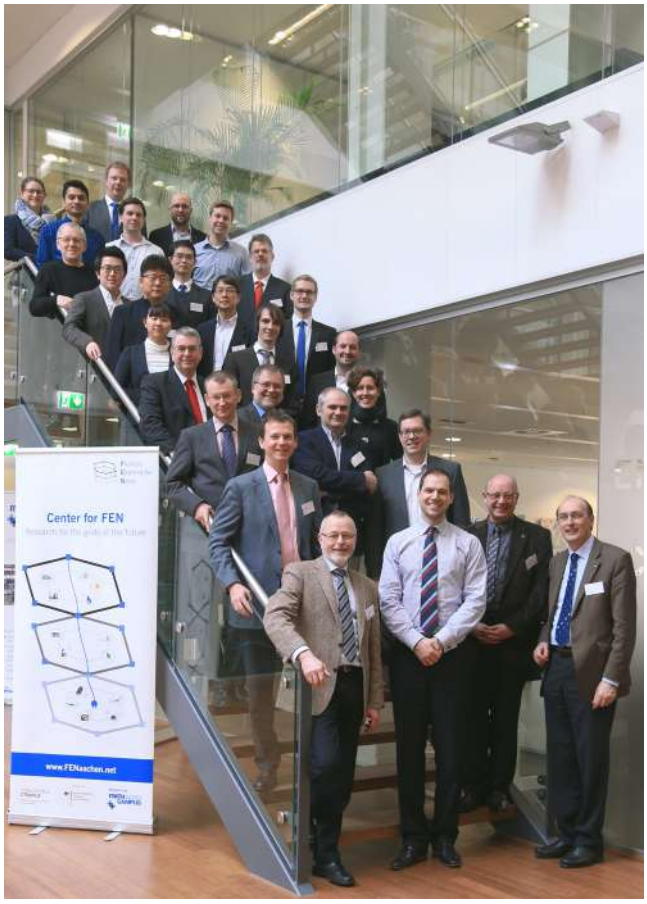
Overview of the MV Consortium

> Slowly but surely, the understanding is growing that with modern power electronics new flexible DC structures in the medium voltage are possible. They offer higher efficiency, can be fully automated and have lower investment and maintenance costs than the conventional three-phase power systems.
>
> **Prof. Rik W. De Doncker**

small towns, cannot be realized with today's three-phase AC system.

The MV Consortium started its research activities at the end of 2014 with the funding initiative "Forschungscampus – öffentlich-private Partnerschaft für Innovationen" by the Federal Ministry of Education and Research (BMBF). 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 possess high innovation potential and societal relevance.

The Forschungscampus FEN is one of nine in Germany. Four connected projects are funded with € 10 million for an initial period of five years (see following page). The projects are coordinated by the Center of FEN and staffed with researchers of RWTH Aachen University institutes. 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.



MV Steering Committee Meeting

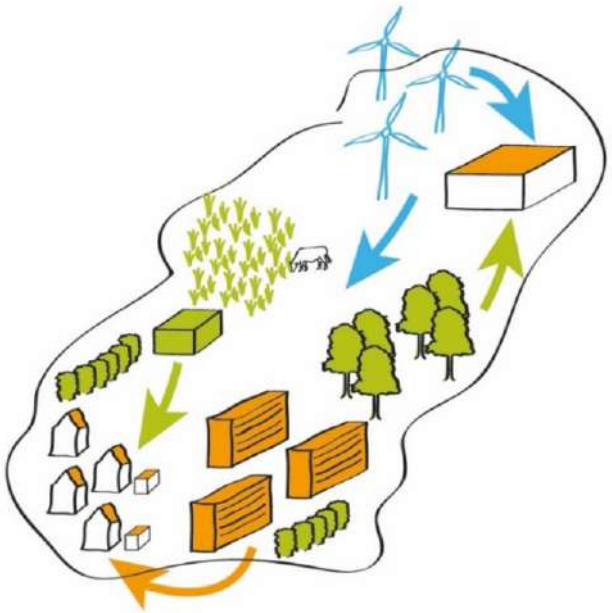
FORSCHUNGS CAMPUS
öffentlich-private Partnerschaft für Innovationen

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

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 and target grid planning methodology for hybrid AC / DC and pure DC grids. The preliminary analyses have already been carried out and the implementation of the target grid planning methodology is in progress. Furthermore, the development of an operation simulation and of a methodology to determine the reliability of supply for DC grids has been started. Additionally, the impact of static electric and magnetic fields on biological systems and a risk assessment of field emissions are under investigation.



Relations of grid components and landscape

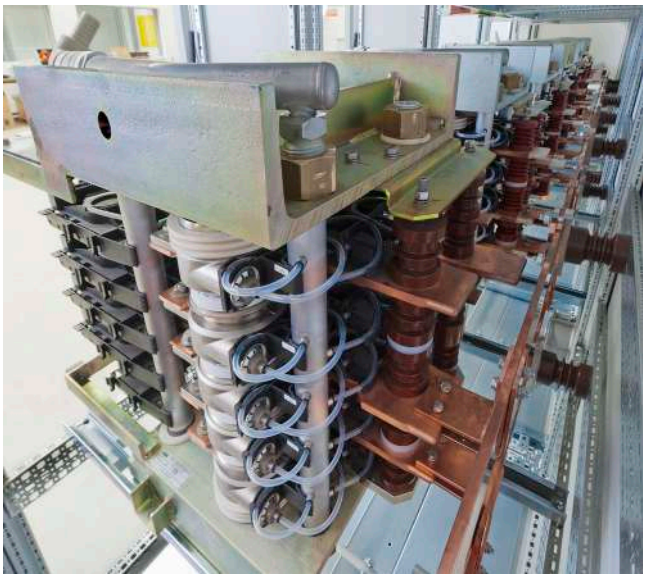
This project also includes interdisciplinary economical, ecological and societal aspects, like the integration of grid components into the landscape and urban environment as well as investigations of technology acceptance by the citizens. In order to gather the opinion of a large pool of people, a Choice Experiment was developed. Part of the outcome of this project will consist of recommendations for grid planning concerning structures and systemic evaluations of future DC grids.
In addition, expected impacts of DC technology on landscape, urban planning and population will be identified.

Electrical Equipment and Grid Technologies (FEN P2)

FEN P2, led by the Institute for Power Generation and Storage Systems (PGS), investigates new materials and components and their effect on the converters and system level.

Regarding semiconductor materials, wide-band-gap semiconductors like silicon carbide are in the scope of research. These materials allow very high switching frequencies. Additionally, having no reverse-recovery losses, these devices completely change the design of power-electronic converters. These devices allow very high efficiencies of DC-DC converters in low-load conditions while no extra components are required to ensure soft-switching operations. Moreover, the wide-band-gap materials allow very high blocking voltage, up to 10 kV and beyond. The first phase focuses on experimental activities on these devices. Special gate drivers and measuring equipment are in development to reduce the common mode currents. The resulting voltage transients in turn have a strong impact on the insulation

materials, for example in medium-frequency transformers. These insulation materials are investigated within the FEN P2 as well.



DC-DC converter at E.ON ERC

Medium-frequency transformers offer efficient voltage transformation and galvanic isolation. Their operation at elevated frequency using power electronics 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.
Consequently, existing modelling approaches of core losses can be verified and adjusted in the next step.

The research on converters strongly focusses on DC-DC converters. Since some of these converters implement soft switching, their efficiency is increased and electro-magnetic interference can be reduced.
Both DC-DC converters for medium voltage and for connecting low and medium voltage levels are investigated. Demonstrators of these converters for 5 MW and 250 kW respectively are in development and will be tested later within the research grid developed in FEN P4.

Control, Operation and Automation (FEN P3)

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.

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 is implemented in close cooperation with PGS.

The control concepts are developed in a hierarchical 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 thus compared and will be derive 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 to be defined at first. 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.

Power Hardware in the Loop Test Setup

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.

An existing Hardware-in-the-Loop (HiL) platform and a scaled-down Power-Hardware-in-the-Loop (PHiL) platform are going to be 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 400V DC multi-terminal low-power lab network, which can emulate the dynamics of the FEN medium voltage DC grid demonstrator of FEN P4. Possible layouts of the scaled-down test setup have been defined whereas first options of component selection have already been discussed. The test setup will be reconfigurable, while reproducing the same dynamic behavior as the demonstrator MVDC grid and its components.

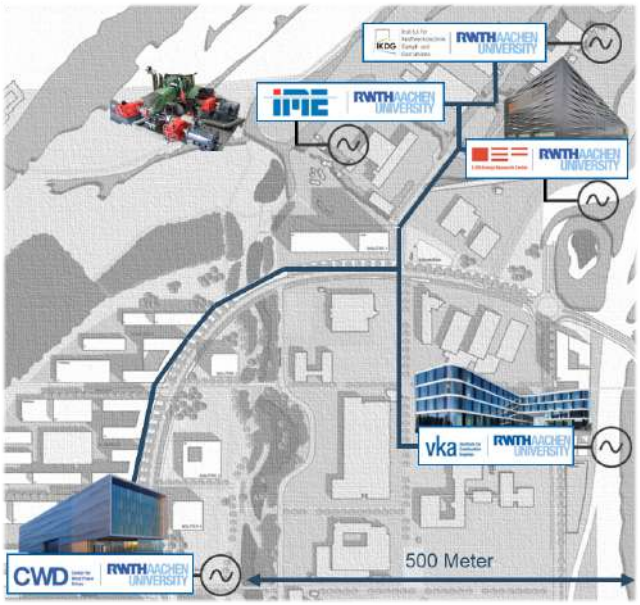
Design, Construction and Testing Campus FEN Research Grid (FEN P4)

FEN P4, led by the Institute for 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 is going to be built and exploited for research purposes on the RWTH Aachen Campus Melaten.

This grid will interconnect several multi-megawatt test-benches of different RWTH Institutes, as shown in the picture on page 27. 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 to the public electricity grid.

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

The first year has been dedicated to the planning of the research grid. The next steps will consist in clarifying the legal aspects in close cooperation with the local grid operator and the administration of the RWTH Aachen University.



Medium Voltage DC Research Grid at RWTH Aachen Campus

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Seed-Fund Projects

Seed-fund projects are short studies which are funded by the Center for FEN itself, supported by industrial partners. These projects investigate special 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 2015 altogether 9 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 1

An investigation of the impact of lightning strikes and differences between DC cables and AC cables in terms of dynamic behaviour was carried out, leading to the definition of requirements of isolation robustness.

Project 2

It can be expected that for a considerable time AC and DC technology will coexist, either as hybrid systems or in close proximity. A particular case has to be considered when DC and AC lines and cables are installed in close proximity. The study revealed findings of mutual electromagnetic coupling between both lines and consequently of undesired effects on the lines or their equipment. Methods were developed that allow an easy analysis of such effects under various conditions.

Project 3

Because of the absence of a natural zero-crossing of fault currents (as in AC grids), fault protection and efficient and cost effective circuit breakers and power switches are of particular interest, which has been a topic of another study.

Project 4

Although electronic power conversion technology is considered quite mature, constantly new options are becoming available, which need assessment of their suitability in the context of DC utility grids. In a related project soft-switching options of state-of-the-art IGBT devices were studied and appropriate test facilities were realized.

Project 5

Electrical equipment in medium voltage grid will also require internal power supplies that drive control electronics and communication interfaces. Though being a side problem, there is a need for low-effort and cost effective, yet efficient auxiliary power supplies, directly operating from medium voltage levels.

Project 6

The objective of this project was the development of a library of models of components for MVDC grids on a DSP cluster available at ERC, which is a highly modular and highly parallel simulation platform for real-time simulations. The relevant scenarios that were considered are MVDC p2p connection, DC collector for offshore wind parks and a multi-terminal MVDC distribution grid.
In addition to the development of the models, an analysis was performed with regards to porting possibilities between Matlab and C++ code to simplify further applications.

Project 7

Another field of interest covers emerging standardization in DC technology and touching on potential DC utility technology. A survey on these ongoing activities has been carried out.

Project 8

The migration from today's AC based distribution grid into a future DC base distribution grid is an potentially enormous task. In a first step refurbishment opportunities which could offer a soft transition were analysed and further research needs were identified. In addition, a simplified grid operation for an AC and DC grid was simulated and compared.

Project 9

A technology-change of such coverage will also eventually affect each individual. Therefore it is necessary that citizen participation is included, starting with information and communication. The usage of various communication formats and channels depending on the characteristics of the technology, the preferences of target groups and the requirements for content were studied by means of methods of communication science.

Further seed-fund projects will start in 2016.

MV Partnership Model

The MV Partnership Model includes several services and benefits for its partners. It offers different partnership options: Business, SME and premium partner. An open partnership model allows interested companies to join in at any time.

Services & benefits	**Business partner**	**SME partner**	**Premium partner**
Votes within the Steering Committee	1	1	2
Right of use to all future and pre-existing IPR of the Research Group	(✓)	✓	✓
Participation on public funded projects	✓	✓	✓
Access to FEN publications* / discount on FEN events	✓	✓	✓
Usage of technical infrastructure / conference rooms	(✓)	(✓)	(✓)
Office space for employees	(✓)	✓	✓
Possibility of renting own office space	✓	✓	✓
Cooperation duration [*years*]	5	5	5
Annual costs	**25.000 €**	**35.000 €**	**50.000 €**

✓ included

(✓) fee-based

* Final reports, studies, PhD-thesis; if available bilingual (German/English)

New Industrial Partners - MV Consortium

Hitachi Europe Ltd.

Hitachi Europe Ltd., a subsidiary of Hitachi Ltd., is headquartered in Maidenhead, UK. The company is focused on its Social Innovation Business - delivering innovations that answer society's challenges. Hitachi Europe and its subsidiary companies offer a broad range of information & telecommunication systems; rail systems, power and industrial systems; industrial components & equipment; automotive systems, financial services; digital media & consumer products and others with operations and research & development Laboratories across EMEA.

HITACHI
Inspire the Next

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All Industrial Partners - MV Consortium

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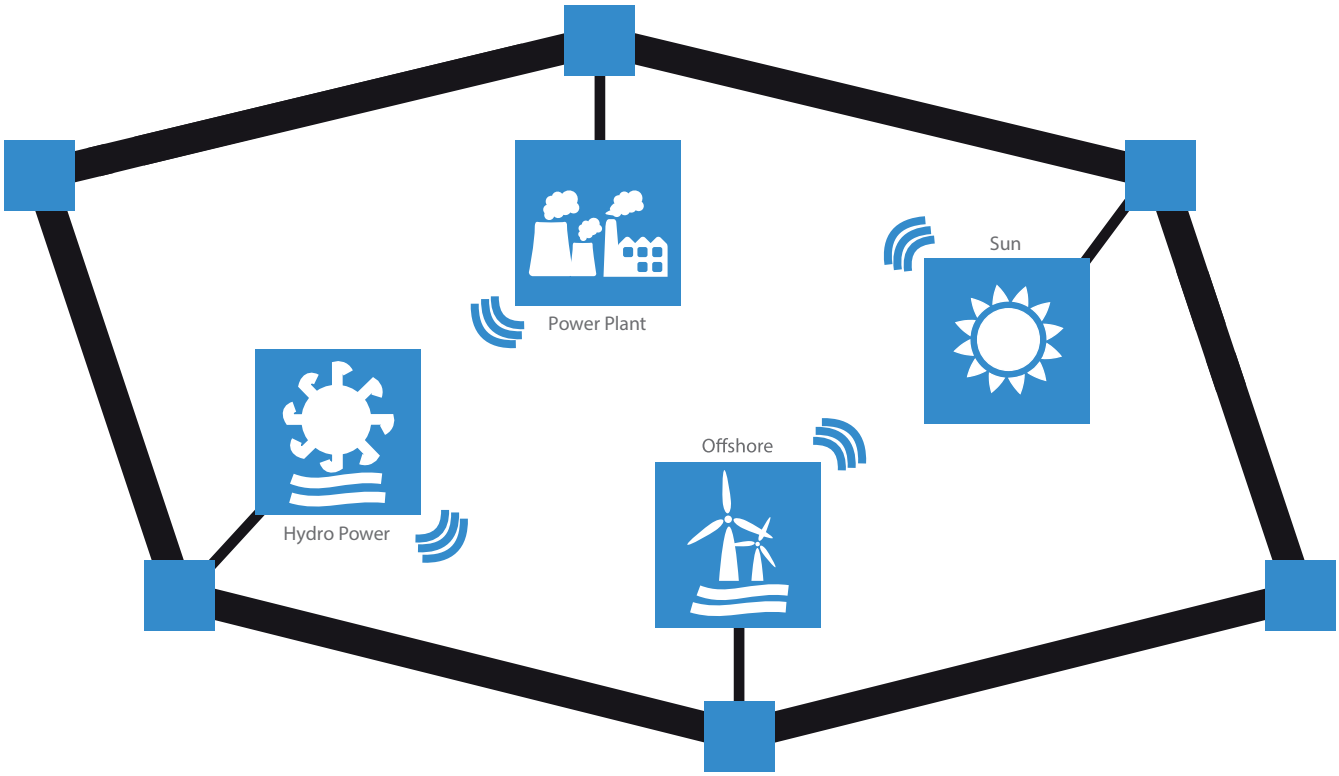
High Voltage Consortium



High Voltage Consortium

Besides, in distribution grids there are also applications for DC technology in overlying 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 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 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 manufactures 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 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

The electrical grid experiences new challenges at all voltage levels. DC technology in high and extra high voltage grids offers promising solutions to meet future requirements and consequently further focused research is necessary.

Prof. Albert Moser

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.

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Further Cooperations and Activities

The Center for FEN participates in several research and exchange programs for students: The Undergraduate Research Opportunities Program (UROP) of the RWTH Aachen University offers Bachelor students three options:

RWTH UROP gives RWTH students the opportunity to be part of the FEN research team. The young academics work with practical orientation in the projects of the Center for FEN and thereby broaden their individual and professional knowledge. UROP projects are not limited to specific periods of the year. Usually, students have the choice to participate in RWTH UROP projects both during the semester and in the lecture-free period. Projects last between one and six months.

UROP Abroad allows RWTH students to conduct research projects at high-profile universities and research institutions in the US and Canada. Projects should last at least two months, and can be conducted during the semester or in the lecture-free period. Per year, up to 15 scholarships can be granted for UROP Abroad projects. The monthly stipend is 600 Euros per month for a maximum project duration of six months.

UROP International targets students from recognized North American universities who want to come to Germany for a ten-week period and conduct a research project at the Center for FEN. The program takes place at the RWTH Aachen University in the calendar weeks 21 to 30 (German numbering). Participants will also receive a German language course and further insight into the German culture.

In the UROP database all current projects of the Center for FEN are advertised:
www.urop.FENaachen.net

In addition to the UROP programs, the Center for FEN participates in an international exchange program, the International Energy Cooperation Program **(IECP)**.
Eleven international universities with a focus on energy, such as the University of Alberta in Canada, participate. The IECP is provided for the period of a project rather than for a Bachelor/Master Thesis.

Information for students interested in the application procedure are available at the following link:
www.iecp.FENaachen.net

UNIVERSITY OF ALBERTA
EDMONTON·ALBERTA·CANADA

RWTH AACHEN UNIVERSITY

IBA Parkstad

IBA stands for Internationale BauAusstellung or International Building Exibition. The IBA idea was conceived in Germany and has expanded to become a creative approach with a proven track record in boosting the economy of the regions concerned. IBA Parkstad is the first IBA outside Germany.

In October 2013, Heerlen, Kerkrade, Landgraaf, Brunssum, Voerendaal, Simpelveld, Nuth and Onderbanken and the Province of Limburg decided to launch the IBA Parkstad.

IBA is looking for innovative, future-proof projects that will be of lasting importance to the development of a town, city or region. IBA does not do any construction work itself, but manages processes.

In the candidate project "DC cable from Aachen University to the District of Tomorrow" FEN, RWTH Aachen University and the World Trade Center Heerlen Aachen will investigate, whether it is useful and possible to lay a low or medium voltage DC cable from the RWTH Aachen Campus to the "District of Tomorrow". Within a Bachelor thesis technical, legal and economical aspects have already been analyzed.

University of Basel

FEN has a cooperation with the University of Basel concerning training opportunities. The research group *inter- and transdisciplinary* of the University of Basel offers trainings and workshops regarding the management of transdisciplinary research associations.
FEN partners have the possibility to participate in these workshops under preferential conditions.

RWTH Aachen Campus

The Center for FEN is part of the Sustainable Energy Cluster on 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 realized 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 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.

Photonics Cluster: new location of FEN Think Tank

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 to new semiconductor structures for utilization in energy conversion technologies (power electronics, phase-change materials) will be conducted.

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 equipments such as a five megawatt test lab, real time digital simulation (RTDS) and hardware-in-the-loop (HiL). These equipments 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.

Smart Logistics Cluster with FEN Think Tank on the 5th floor

Chronicle 2015

14-15 JAN Symposium BMBF Forschungscampus, Berlin

11 FEB Presentation at eWorld, Essen, by Prof. Monti

26 MAR Presentation at E.ON ERC Annual Meeting, Aachen, by Prof. Monti

15 APR Presentation at Hannover Messe, Hannover, by Prof. Monti

01 MAY Hitachi becomes new industrial partner in MV Consortium

19 JUN 3. Low Voltage Workshop

22-25 JUN FEN is Gold Sponsor at the 6th International Symposium On Power Electronics For Distributed Generation Systems (PEDG), Aachen

09 JUL Presentation at DG Energy Meeting, Brussels, by Prof. Monti

01 AUG Member of Institute of Electrical and Electronics Engineers (IEEE)

07 AUG Funding approval for the reserach project FlAixEnergy, funded by BMWi

FLAIXENERGY

19 AUG DKE Meeting standardization roadmap DC

24 AUG Presentation at IKT.NRW Cluster, Bochum, by Prof. Monti

15 SEP FEN becomes VDE member

VDE

15-16 SEP

Final event FINESCE Smart Energy, Berlin

01-02 OCT

FGE Meeting, Aachen

05 OCT

Opening ceremony of the Forschungscampus FEN, Aachen

29 OCT

FEN Day @Siemens, Erlangen

01 NOV

Participation in theme park living & energy of the event Aachen 2025, Aachen

02 NOV DKE Meeting standardization roadmap DC

04 NOV Participation in EIT Digital Meeting, Berlin, by Prof. Monti

16 NOV FEN at ETG Congress, Bonn

23 NOV 1st LV steering committee with founding members, Aachen

01 DEC Presentaion at Xyna Conference (GIP), Wiesbaden, by Prof. Monti

Future 2016

JAN — **JAN** Official start of LV Consortium

14 JAN — DKE Meeting standardization roadmap DC

26-27 JAN — 3. Conference Zukünftige Stromnetze für Erneuerbare Energien, Berlin

10 FEB — Convention Zukunftsenergien, Essen

10-12 FEB — EnInnov 2016 at TU Graz, Graz

15-18 FEB — Convention E-World energy & water, Essen

FEB — **FEB** FEN Intranet for FEN partners

15-17 MAR 10th International Renewable Energy Storage Conference (IRES 2016), Düsseldorf

22-23 MAR FEN sponsor at InnoGrid2020+, Bruessels

20-24 MAR Applied Power Electronic Conference (APEC), Long Beach

04-08 APR IEEE ENERGYCON, Leuven

25 APR Battery Power Day NRW, Münster

10-12 MAY PCIM Europa, Nürnberg

23-26 MAY International Instrumentation and Measurement Technology Conference (I2MTC), Taipei

31 MAY — 2. Symposium of the BMBF Begleitforschung, Berlin

JUN — New FEN Website — **JUN**

14-15 JUN — CIRED 2016, Helsinki

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

27-30 JUN — 7th International Symposium On Power Electronics For Distributed Generation Systems (PEDG), Vancouver

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

04 JUL — Event with Federal Ministry of Economic Affairs and Energy (BMWi), Aachen

11 JUL — Integration of Sustainable Energy Conference (iSEneC)

17-21 JUL — IEEE PES General Meeting, Boston

21 AUG — CIGRE 2016, Paris

AUG

AUG Move FEN Think Tank in Photonik Cluster

18-22 SEP 8th Annual IEEE Energy Conversion Congress & Exposition (ECCE 2016), Milwaukee

28-30 SEP IEEE International Workshop on Applied Measurements for Power Systems, Aachen

06-09 NOV The 10th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion, Belgrad

05-09 SEP ECE 2016 ECCE Europe, Karlsruhe

23-25 SEP Aachen 2025

09-12 OCT IEEE PES Innovative Smart Grid Technologies, Ljubljana

07-08 NOV VDE Congress, Mannheim

University Partners

Institute for Automation of Complex Power Systems

The main topics of research covered *ACS* 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

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

FCN contributes applied theoretical and empirical research to FEN in the areas of energy economics, energy management, energy policy, and the management of grid-related financial risks and uncertainties. A particular thematic focus is put on the perception and acceptance of the general public regarding the introduction of MVDC grid installations, taking into account political support schemes, regulatory frameworks, and the characteristics of ultra-long-lived investment goods. Moreover, in the economic research conducted particular emphasis is put on spatial aspects (cost-benefit heterogeneity, micrositing issues etc.).

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Institute for Power Systems and Power Economics

In the context of FEN, *IAEW* is project leader for Project 1 (Modelling, Planning, Conceptual Design and Assessment of Future Grids) as one of the four BMBF projects and focuses on grid planning and grid operation simulations, 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 responsibilities of research of *IEM* 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 research focus of *IFHT* in the context of FEN is on topics like transmission lines and cable technologies, protection and switching components, insulation coordination and diagnostics. Its project contribution in those fields includes simulations as well as practical tests.

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Institute for Power Electronics and Electrical Drives

The research of *ISEA* 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 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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Institute and Out-patient Clinic of Occupational Medicine

For FEN *IASA* 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 contribution of *GGE* to FEN includes 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 contribution of *HCIC/TL/TK* 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 *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 result 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 *ISL* explores the applicability of dc infrastructure into the urban fabric. The institute identifies the urban structural impact, possible public utilizations of dc applications, consequences for urban planning procedures, and additional benefits to the people by an integrated infrastructure. The research will be conducted by a mixed-method approach, including e.g. field work, data aggregation, literature review, workshops and spatial explorations. The aim is to qualify starting points and procedures to transform urban quarters to more sustainable socio-technical and socio-spatial living spaces. Finally, the ISL wants to extract and synthesize principles of the findings to be transferred into selected spatial contexts in Germany, Europe, and the Global South.

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Institute of Political Science

The *IPW* contributes to FEN with research in the field of futures studies as well as science, technology and society studies (STS). 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 *LA* 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 elementary 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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Facts and Figures

FACTS

8 Industrial Partners LV

12 Industrial Partners MV (+ 1)

15 RWTH Institutes

260 m² space for FEN Think Tank

Ø36 Researchers working on projects (+ 18)

PROJECTS

5

PUBLICLY FUNDED (+ 1)

Four projects 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.
One project is funded by the Federal Ministry of Economic Affairs and Energy (BMWi).

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CONSORTIUM PROJECTS

have been launched in 2015. Overall, 13 consortium projects have been launched. The results of these projects belong to the Center for FEN and are shared with all partners.

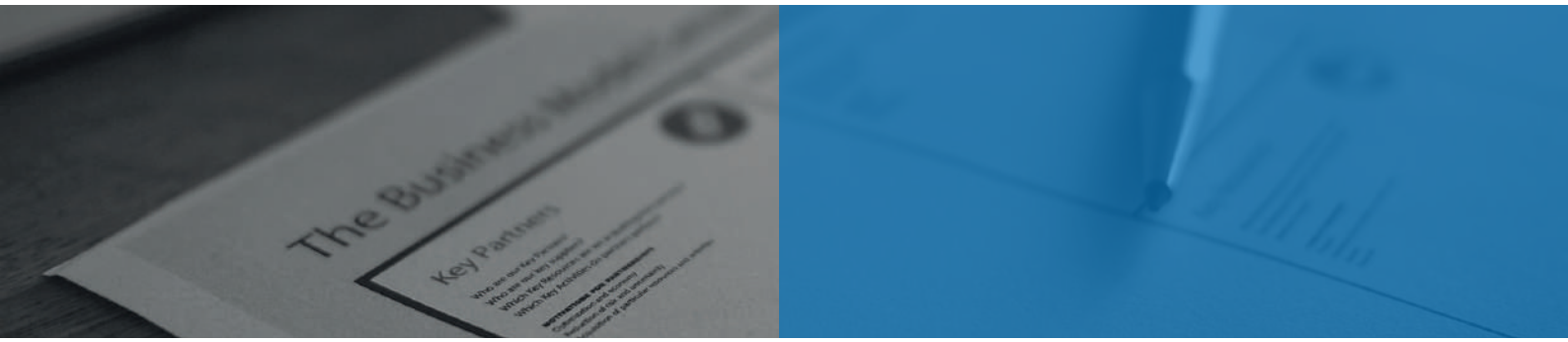
PUBLICATIONS

23
Conference Papers & Journals
In total: 53

5
Dissertations
In total: 12

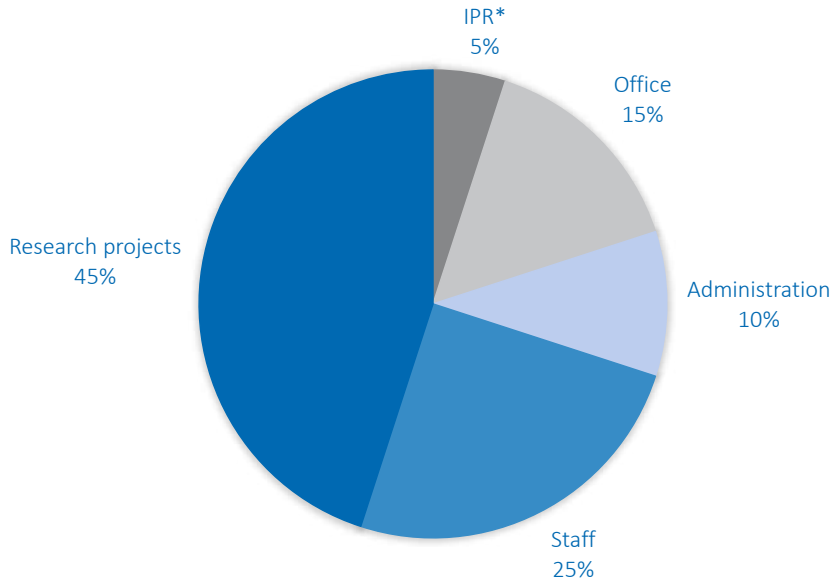
12
B.Sc. & M.Sc. Theses
In total: 30

17
Further Publications
In total: 27



BUDGET FINANCE

TOTAL BUDGET FROM FNP MV (515K€)



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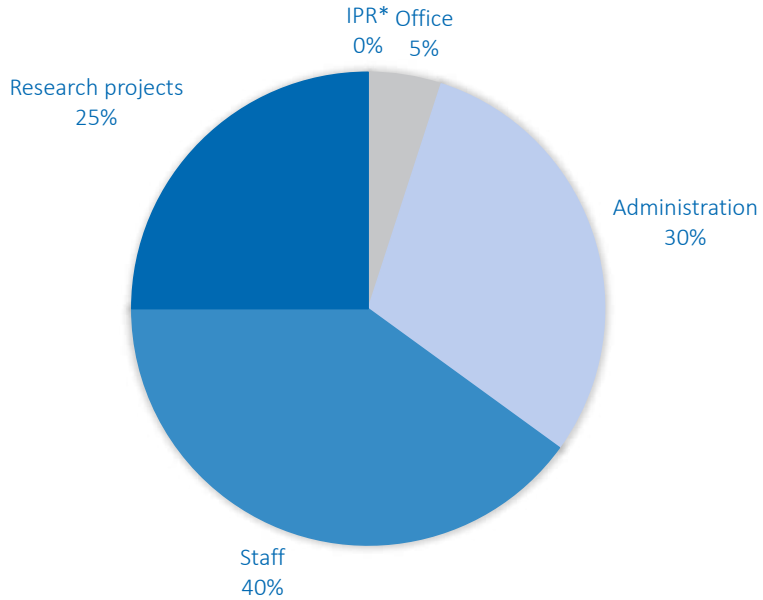
TOTAL BUDGET FROM FNP LV (140K€)



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