ABB Schweiz AG
Corporate Research
Segelhofstrasse 1K
5405 Baden-Dättwil
Switzerland
Contact Center: Tel. +41 (0)844 845 845

contact.center@ch.abb.com

ABB Corporate Research
Switzerland

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“The electric light did not come from the continuous improvement of candles,” says Oren Harari.

In each of ABB’s seven corporate research centers – located around the world – scientists strive to develop cutting-edge technological achievements that will help strengthen ABB’s four divisions.

These highly motivated and highly qualified corporate research specialists collaborate closely with ABB business units and leading universities, partners and startups to challenge the limits of science and deliver the innovation that drives the Group's success.

At the ABB Corporate Research Center in Switzerland, scientists have been delivering a stream of innovative technologies since 1967.

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ABB Group

Fundamental knowledge is the key to innovation.

ABB is a pioneering technology leader in electrification products, robotics and motion, industrial automation and power grids that serves customers in utilities, industry, transport and infrastructure globally. Continuing a more than 125-year history of innovation, ABB is today writing the future of industrial digitalization and is driving the Energy and Fourth Industrial Revolutions. ABB operates in more than 100 countries with over 132,000 employees.

Global R&D at ABB
Fostering innovative research

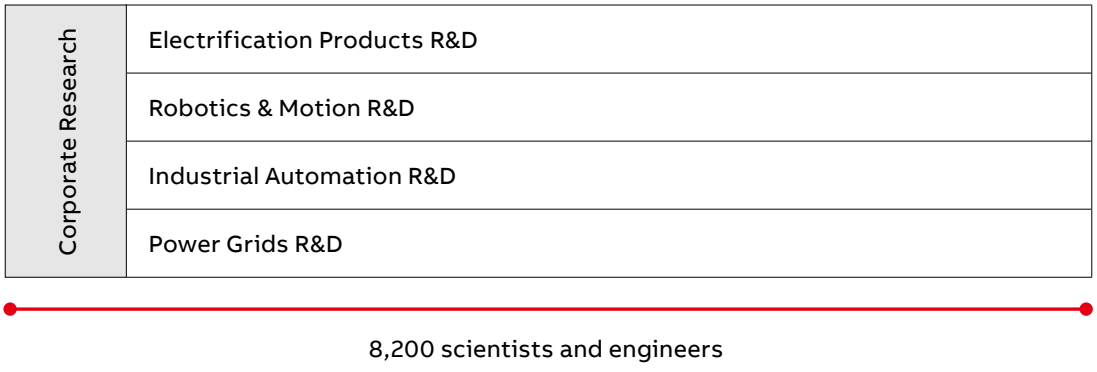
A truly global organization, ABB has over 8,200 scientists and engineers working all over the world. ABB's R&D focuses on breakthrough developments that address challenges such as the integration of renewable power sources into the grid; how to enhance power network efficiency, reliability and flexibility; and how to improve industrial resource efficiency and asset productivity.

Research and development at ABB is organized into Division R&D and Corporate Research. Division R&D is conducted in four global division R&D organizations. Corporate Research is organized into seven labs, the heads of which report to the Chief Technology Officer (CTO).

ABB Corporate Research is primarily responsible for technology scouting and technology development projects. The division R&D organizations focus their attention on product development projects.

R&D at ABB

Division R&D and Corporate Research



Corporate research at ABB

Research centers close to talent and customer base.

As well as technology scouting and technology development, corporate research is also responsible for the transfer of new technologies to the division R&D organizations, a step that is crucial for successful product development.

R&D projects are grouped into eight research areas, which are headed by group research area managers. Researchers within all areas collaborate with about 70 top universities worldwide, with suppliers, with startups and with researchers in ABB's business units.

The research areas are:
- Control
- Software
- Power electronics
- Sensors
- Mechanics
- Switching
- Materials
- Electromagnetics

More than 800 scientists working in these research areas are located in the seven corporate research centers throughout the world. These centers are in Switzerland, Sweden, the United States, China, India, Germany, and Poland.

Founded in 1967, the ABB Corporate Research Center in Baden-Dättwil, Switzerland was originally established under ABB's predecessor company, BBC. Today, this research center has about 200 employees from more than 35 different countries. The center is administratively connected to ABB Switzerland but reports to the global research organization like all other research centers.

The research center in Switzerland focuses on:
- Automation
- Power electronics
- Energy and materials
- Power products and systems

ABB Ability™ digitalizes industrial automation

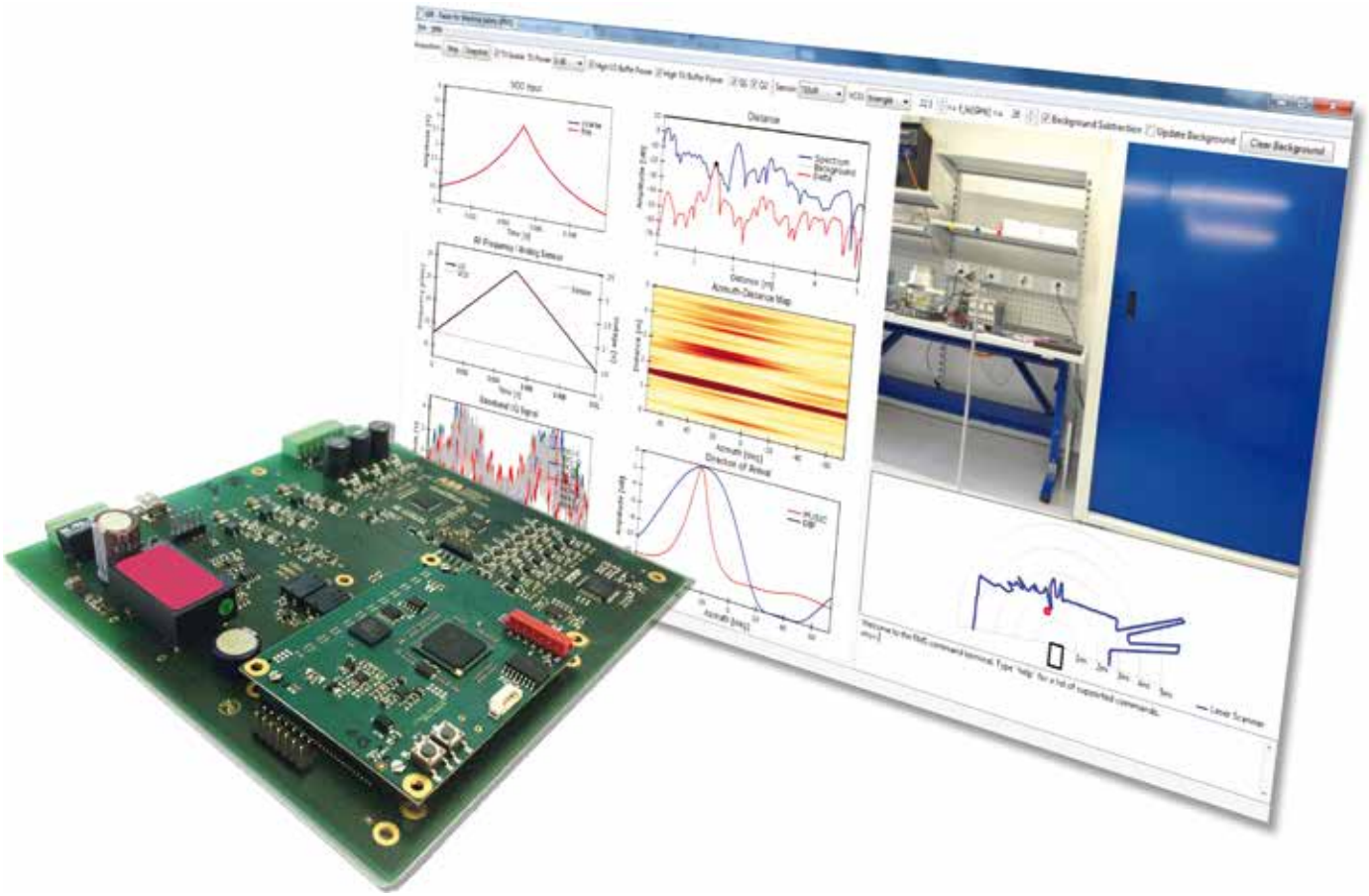
For centuries, engineers have been automating processes in an effort to increase efficiency, improve safety, availability and reliability, and free humans from otherwise dangerous or repetitive activities. Today, sensors – rather than the human senses – can be relied upon to observe a process accurately. A processor equipped with algorithms for controlling or adjusting the process then provides the intelligence that decides how to influence the process, and actuators carry out the action needed to produce the desired result. These automation systems differ in architecture – distributed or centralized – and in size, complexity, and the speed with which they react.

Industry is now moving to the next level of automation systems, which not only execute simple control loops or rule-based processes but which optimize overall performance based on a holistic understanding of the system state, prediction of the future and even automatic adaption of the process abstractions. ABB is driving this revolution in automation systems with ABB Ability.

ABB Ability is a unified, cross-industry digital capability – extending from device to edge to cloud – with devices, systems, solutions, services and a platform that enable ABB customers to know more, do more, do better, together. ABB Ability connects customers to the power of the Industrial Internet of Things (IIoT) and, by exploiting ABB's services and expertise, turns data insights into the direct action that "closes the loop" and generates customer value in the physical world.

In many ABB Ability applications – or, indeed in virtually any industrial automation setting – it is the field instruments that are closest to the process; they are the foundation of the industrial automation pyramid. ABB is a leading manufacturer of field instruments – both the sensors for physical properties and the analytical instruments that are the sensors for chemical composition. ABB Corporate Research Switzerland contributes to these products with research in optics, laser spectroscopy, radar applications and acoustics.

An essential element of automation is the signal processing executed in electronics embedded in the devices: Clever processing of sensor data delivers a more detailed observation of a plant's condition, while big-data analytics provides in-sights that were not possible before. Advanced process optimization increases productivity and energy efficiency.



System architecture

With systems becoming smarter and more digital, their inherent complexity rises. In the IIoT, systems comprise numerous heterogeneous devices that communicate through different wireless and wired technologies. The main questions that researchers need to answer are: How can we build systems that are correct, dependable, scalable, secure, safe and that deliver high performance? How can we connect such systems to the cloud while ensuring that the data arrives on time and in a secure way? To answer these questions, ABB Corporate Research is developing the next generations of software and systems architecture. These support scalability of applications – from resource-limited, low-end devices to high-performance servers – and deployment anywhere between the sensor and a remote data center.

Real-time systems are essential for many power and automation applications to ensure safe and optimal operation. The increasing computational power of automation systems and the adaptation of general-purpose operating systems enable more and more applications to exploit real-time monitoring and control. At the same time, the observation intervals for existing real-time systems are becoming shorter. ABB Corporate Research in Switzerland focuses on several aspects of real-time systems and provides corresponding solutions, including system architectures, dependable digital communication and real-time testing systems.

Security and privacy for cyber-physical systems

The age of cloud computing and ubiquitous Internet connectivity poses new security challenges to digital control systems, such as the protection of the confidentiality of customer process data in the cloud. For example, ABB offers predictive maintenance services for devices with convenient cloud access. Customers demand assurance that this data is treated securely all the way from the embedded sensor through the cloud into the customer's web browser.

To guarantee confidentiality, the revolutionary approach of homomorphic encryption is used to carry out computations on encrypted data. Sensitive data can thus be encrypted and sent for analysis to ABB Ability without sharing the key. Only the customer can access the data and results. The team has found ways to massively reduce the computational overhead of homomorphic encryption, thus making it usable in ABB Ability in an effective way.

Blockchain is another technology that helps to establish secure transactions between parties that do not trust each other. The team is investigating new business-use cases for which the blockchain and its computational effort can be justified as well as alternative technologies that incur significantly less overhead.

Intelligent operation in process industries

The increasing push for flexibility and efficiency in process operations is forcing plant owners to invest in intelligent systems that help steer a multitude of process variables in an optimal way to optimal targets. This trend is coupled with a strong drive towards autonomy to enable unmanned operation in remote sites.

ABB Corporate Research in Switzerland conducts research with interdisciplinary teams on optimization and process-modeling technologies to implement intelligent solutions for these increasingly complex processes. By using methods such as data analytics and machine learning, the teams can also reduce the lifecycle cost and increase the penetration of these solutions.

For example, the efficiency of rotating machines – such as compressors and pumps – can be optimized by monitoring their performance and displaying the derived information on performance maps. Applying these methods to gas pipeline compressor stations can significantly cut running costs and reduce CO_2 emissions.

Embedded optimization for automatic control

The IoT is built up of smart devices whose level of smartness ranges from comprehensive monitoring to fully autonomous behavior. While some computations are outsourced to the cloud, others have to be performed by the device itself, mostly for safety, reliability or cost reasons. This edge computing requires hardware that is embedded into the device and algorithms that run reliably without human intervention.

ABB Corporate Research focuses on the embedded computations needed to run advanced control algorithms that solve challenging optimization problems in real time. A recent success story involves model predictive torque control (MPTC) for ABB load commutated inverter medium-voltage drives. Here, a nonlinear constrained optimization problem is formulated and solved every millisecond to determine the best selection of firing angles to follow a desired torque trajectory while satisfying operating constraints. MPTC significantly increases the robustness of the drive against grid voltage disturbances and thus the availability of critical customer operations while reducing reactive and active power consumption due to a better steady-state operating point.

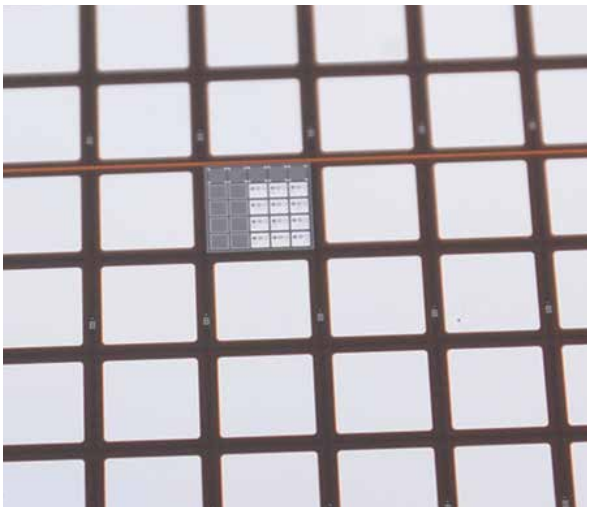
Power electronics

Where high voltages and currents have to be controlled, power electronics devices are to be found: locomotives, robots, variable-speed drives, furnaces and a multitude of other industrial and transportation applications exploit the advantages of power electronics. ABB, a pioneer in this field, is continuously improving the power density, efficiency, functionality and reliability of power electronics equipment. A key asset in this endeavor is ABB Corporate Research Switzerland's PEARL (Power Electronics Advanced Research Lab) facility, the establishment of which means that the Swiss research center now has all core competencies – semiconductors, packaging, thermal integration, topologies and control – under one roof.

PEARL – for the next generation of power semiconductors

The PEARL facility enables research into next-generation power semiconductors, modules and applications. New devices are designed in-house then samples are fabricated in the lab's clean-room. The semiconductor dies can then be packaged and integrated into larger power modules (eg., LinPak).

These power modules are then arranged in circuits with optimized topologies to improve existing, or enable new, applications. To fully exploit the potential of modern power electronic converters, an overall optimization of semiconductors and converters is required. To this end, the PEARL also provides the possibility to test semiconductor devices, as well as full converters, with respect to performance and reliability.



Leading SiC developments

Silicon carbide (SiC) semiconductors have many advantages over silicon-based devices: they can sustain much higher currents and voltages, they switch up to ten times faster, they can operate at up to 250 C compared to silicon's 150 C and their higher thermal conductivity means they are much easier to cool. ABB Corporate Research Switzerland has long experience in, and a fundamental understanding of, the science of SiC. To exploit the benefits of SiC, corporate research engineers in ABB Corporate Research Switzerland are developing SiC devices, such as Schottky diodes and MOSFET switches, which can be used in ABB products.

BORDLINE BC battery charger achieves the highest power

An example of an ABB SiC-based product is the BORDLINE BC battery charger. SiC power semiconductor technology enables class-leading power density and performance by dramatically reducing size and weight, and cooling requirements, as well as increased system efficiency – all critical factors for rail operators. ABB Corporate Research supported this innovation by assessing the reliability and robustness of SiC devices and helping to select the devices that best match this demanding application.

ABB's SiC LinPak power module for future LV and MV applications

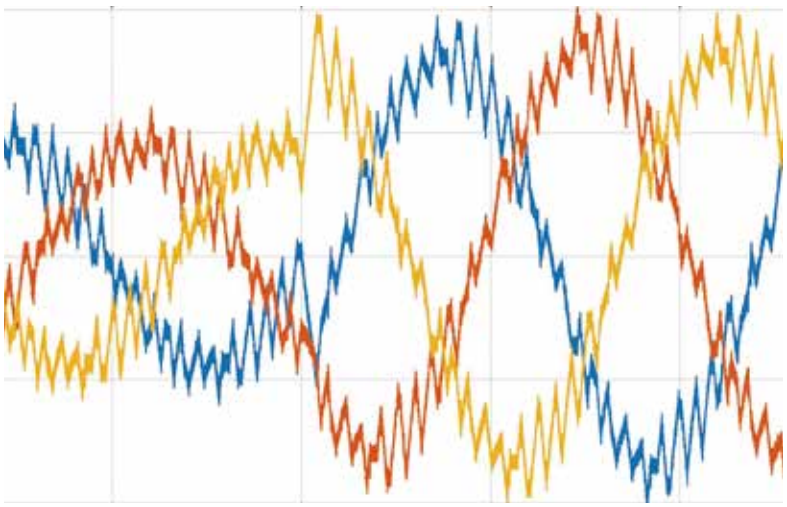
An innovative SiC power module design based on the ABB LinPak module enables more compact and highly modular converter systems by paralleling many devices of next-generation, wide-band-gap SiC power semiconductor devices. Novel assembly technologies expand the range of candidate applications and enable further improved efficiency in LV and MV products.

ABB's StakPak power module stabilizes electricity grids

StakPak is a family of high-power insulated-gate bipolar transistor (IGBT) press-packs and diodes in an advanced modular housing that guarantees uniform chip pressure in multiple-device stacks. ABB's class-leading StakPak power module technology enables very high transmission power so that emerging Mega Cities can be efficiently connected to distant renewable power generation (hydro, wind, solar). ABB Corporate Research Switzerland is heavily involved in the development of cutting-edge power module material combinations and structural concepts to provide highly reliable and failure-safe package solutions for HVDC transmission applications.

Innovative cooling technology for harsh environments and renewables

ABB's innovative and highly efficient self-contained cooling system uses phase transition and thermosiphon technology. With the simplicity of air cooling and with the power density of liquid-cooled systems, it provides low maintenance and easy commissioning – ideal for any outdoor application. ABB Corporate Research performed the fundamental scientific work needed to design the cooling system and carried out the tasks needed to move it into the product development phase. The cooling system is currently employed in drives, photovoltaic inverters and dry trans-formers.



Model predictive control for drives and power converters

Model predictive control (MPC) is a control technique that has its roots in the process industries. MPC predicts the future behavior of the system to be controlled via a mathematical model and solves an optimization problem to ensure that the system is steered in the best way possible. ABB Corporate Research in Switzerland has now investigated MPC further and has applied it to real-time power converter control so that the best dynamic performance and robustness can be achieved. The first successful application has been demonstrated within MV drives.

Galvanically insolated modular power conversion

The minimum size of a power transformer is essentially determined by the laws of physics as the core must have certain dimensions to accommodate the magnetic field. In terms of making this grid component smaller and lighter, the laws of physics, fortunately, provide some leeway in the form of operational frequency. The higher this is, the smaller the core required. ABB has taken on the challenge and has developed a prototype power-electronic transformer for traction applications. ABB Corporate Research supported this pilot application and is investigating future technologies and applications for the related topic of galvanically insulated modular power conversion.

Energy and Materials

The desire to understand energy and material is among the most fundamental forms of scientific enquiry and one that has inspired some of the greatest scientific minds of history. Today, ABB's research activities in this area draw from knowledge and expertise in a broad range of scientific disciplines, including material science, chemistry, physics and electrical engineering. ABB's involvement in energy and materials ranges from fundamental and first-principle understanding to advanced work on material development and process technologies.

In the physics domain, for example, the first-principle understanding of charge transport in high-voltage components as well as other complex multiphysical interactions are topics for exploration. This knowledge is used, for instance, in the system simulation of circuit breakers. In the applied physics area, ABB Corporate Research in Switzerland helps optimize thermal management to improve power ratings and product footprints. The Swiss research center is the focal point of expertise in energy storage solutions – in particular, battery systems. Researchers contribute to the full value chain from understanding battery cells, through integration into modules and cooling aspects, right up to battery systems and business evaluation.

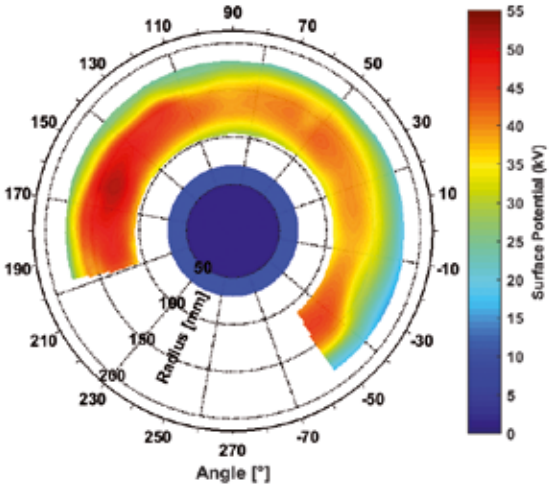
In the area of material research and manufacturing methods, activities include the development of novel metallic compounds as high-performance contact materials in circuit breakers. The research center advances the development of hard permanent magnets by innovative methods such as 3-D metal printing and spark plasma sintering. Deep expertise in zinc-oxide varistor technology is applied to the traditional application of surge arrestors and also to the exploration of future trends such as solid-state circuit breakers.

Insulation technology is a strongly multidisciplinary field that seeks new insulation concepts to increase ratings in both AC and DC applications, while also improving safety, extending lifetime and making manufacturing (including additive manufacturing) more efficient. Work in this area covers a variety of applications including transformers, bushings, gas-insulated switchgear, HV and MV components and accessories. A wide range of insulation media – from gas and liquids to solid materials including thermosets, thermoplastics, elastomers and composites – are also addressed.

Physics of high-voltage DC insulation

An important requirement for the design of gas-insulated systems under DC voltage stress is to optimize the resistive electric field distribution. An intrinsic difference between DC and AC is that the DC conductivity of insulation materials is strongly temperature-dependent, while their permittivity varies only weakly with temperature.

High-precision analysis of temperature and electrical field distribution is now possible by using newly developed multiphysics simulation tools. The combination of temperature and electric field dependency in insulating materials, which leads to accumulation of space charges and surface charges, can now be examined in detail. Calculated fields are validated by the measurement of insulator surface potential at real-scale, and nominal voltage and current stress. These measurements are made in the lightning impulse laboratory. This capability is a world-class development enabled by ABB Corporate Research.



Powder metallurgy of electrical contacts

Key components of electrical switchgear are the electrical contacts. Their high electrical conductivity and arc erosion resistance requirements call for composite materials that are tailored to the specific low-, medium- or high-voltage switchgear application. Commonly used materials include silver-metal oxide, silver-tungsten carbide, copper-chromium and copper-tungsten. New contact materials developed at ABB Corporate Research in Switzerland are able to achieve an electrical lifetime similar to, or even higher than, commercial materials while saving on precious metals, thus reducing costs significantly.

System simulations for rapid design of gas-insulated circuit breakers

In a gas-insulated circuit breaker, the electrical current is interrupted by blowing cold gas at an arc formed between two electrical contacts. To break the current, this cooling has to happen at just the right moment – when the AC current goes through zero – and with a sufficiently high blowing pressure. In order to perform systematic breaker design studies, methods are needed that efficiently simulate the blowing pressure for a given breaker configuration. Such a simulation requires a model of the complete breaker system, consisting of the interruption zone containing the hot plasma, the surrounding volumes for the cold gas and the (mechanical) drive operating the breaker. In close collaboration with development teams in the power grids division, ABB Corporate Research in Switzerland has developed a framework for modeling such circuit breakers. Based on the modeling language Modelica and comprising an extensive model library for all relevant breaker components, it is an enabler for systematic design studies that can bring breaker developent to the next level

Energy storage

Battery and battery charging technologies represent fertile fields in the search for sustainable transport. In 2016, Geneva's public transportation operator, TPG, decided to convert its route 23 to fully electric with opportunity charging mode. The flash-charging connection technology used is the world's fastest: It takes less than one second to connect the bus to the charging point and the onboard batteries can then be charged by a 600 kW boost lasting 15 seconds in the time that the bus is at the bus stop anyway. A further four- to five-minute charge at the terminus fully recharges the batteries. ABB's scope of delivery included converters, motors and the charging stations. Li-ion experts from Corporate Research supported the design and sourcing of both the onboard and the wayside battery storage systems with performance predictions and testing.

Insulation materials for power products

In general, high-quality insulation materials are essential for the operation of the power grid: Especially at medium and high voltage, power products need to be insulated to withstand short- and long-term thermoelectrical but also mechanical and other environmental stresses.

For the EasyDry transformer bushing, new material concepts based on thermoplastics, thermosets and elastomers together with novel manufacturing processes were applied to design a bushing that is completely oil- and paper-free. This modern technology sets new standards regarding quality, reliability, safety and lead time. The basic material concept and manufacturing method were developed in the ABB Corporate Research in Switzerland.

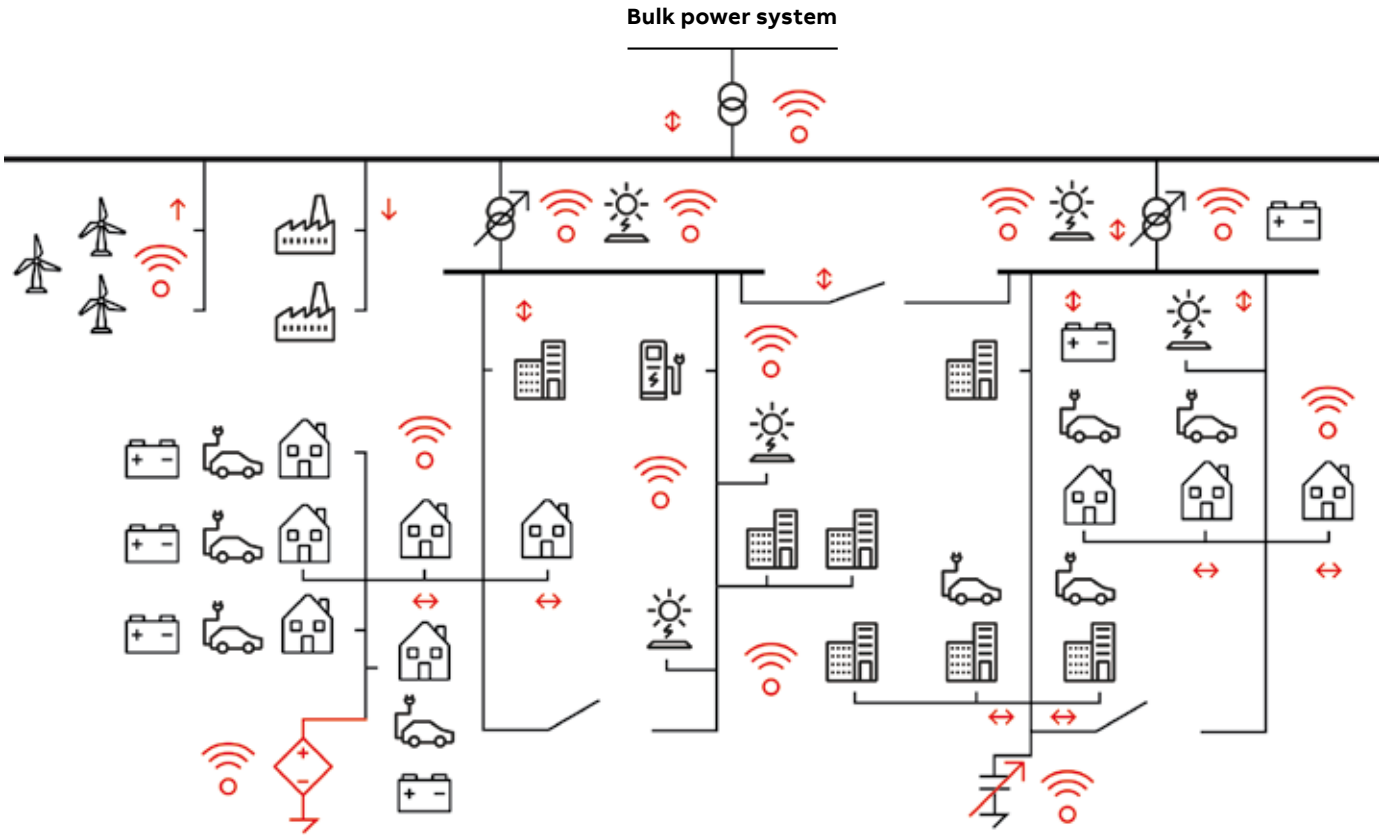
World's first gas-insulated switchgear with new eco-efficient gas mixture

In 2015, ABB made a significant breakthrough in gas-insulated switchgear (GIS) technology by commissioning the world's first HV and MV GIS bays with the new eco-efficient gas mixture AirPlus™ as an alternative to the widely-used greenhouse gas SF_6. ABB Corporate Research in Switzerland made a strong contribution to this technology leap by evaluating the dielectric performance and the compatibility of the new insulation gas with the material components in the GIS under various operating conditions. By means of chemical aging experiments and fundamental analyses, different possible reaction paths were studied and risks under various conditions assessed. Clear recommendations for the selection of compatible materials in the new eco-efficient GIS could then be given. As a consequence, ABB launched the MV products SafeRing AirPlus for secondary applications and ZX2 AirPlus for primary applications.


ABB
ABB

Power products and systems

Modern life depends on electricity. ABB also develops and supplies the power products for the infrastructure that brings this electricity to homes and workplaces. ABB also develops and supplies software solutions for the planning and control of power systems. The work carried out by ABB Corporate Research establishes the scientific and engineering fundamentals of power systems and of many of the power products involved.



Power systems of the future

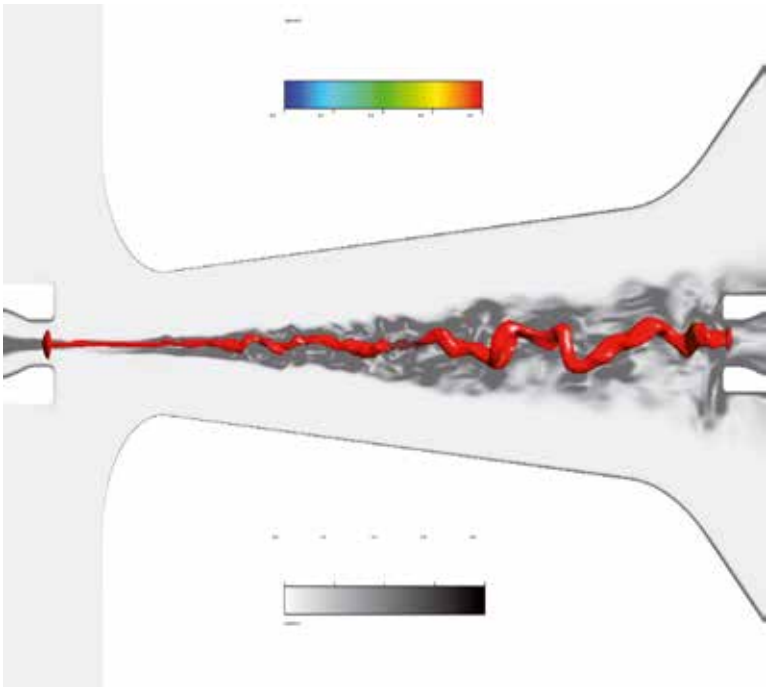
ABB Corporate Research's Power Systems of the Future research program uses a framework of data collection, scenario generation, and technical and economic analysis to investigate how new technology, policy and business models can shape the electric power sector.

The impact of the changing generation mix brought about by the increase of centralized and decentralized renewable power generation (wind, solar, bio) is assessed on various timescales. These timescales cover long-term infrastructure and resource adequacy planning, through daily operation of the grid in a quasi-steady-state for generator scheduling and wholesale energy auction analysis, down to transient analysis for angle, frequency and voltage stability. The techno-economic framework developed by ABB Corporate Research in Switzerland quantitatively evaluates potential technical challenges such as the increasing need for adequate operating reserves and transmission or distribution feeder capacity; reduced system inertia and short-circuit capacity; and the increasing need for dynamic voltage support in scenarios with a very high share of variable generation connected through converters. In the near future, many distribution networks will host unprecedented levels of active components such as small-scale solar, wind and storage, electric vehicles and charging infrastructure. To seamlessly integrate these components without jeopardizing the reliability and the security of the power delivery, the grid operators will have to coordinate the interactions of these resources with the grid using advanced metering and sensing infrastructure. Such an active distribution grid can increase the utilization of variable energy resources while providing additional services to the transmission grid.

HVDC grid control and grid integration of power converters

Average transmission distances are increasing due to the rapid development of utility-scale renewable energy resources, making HVDC (high-voltage direct current) the prime candidate for grid reinforcement. In addition to its main role of transporting power, the superior controllability of HVDC allows it to provide voltage support and significantly boost the transfer capacity of the legacy parallel AC grid. ABB Corporate Research in Switzerland has developed novel control schemes to exploit HVDC capabilities and thus maximize overall grid transfer capacity.

Behind-the-converter load and generation scenarios are becoming increasingly common. This presents the challenge of avoiding disturbances arising from the interaction between different grid-connected converters as well as between the converters and the grid. The Swiss corporate research center has developed cutting-edge tools for the large-scale analysis of grid-connected power converters and has applied them, for example, to design active damping controls that enable the secure operation of HVDC-connected wind farms.



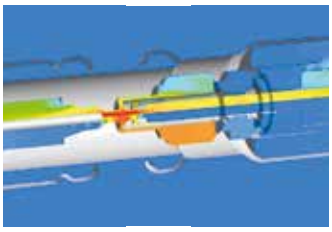
Circuit breakers

Circuit breakers are electrical switches designed to protect the power grid from damage caused by short circuits. They are the elements that segregate the healthy from the faulty part of the grid. Circuit breakers are ideal conductors in the closed position, ideal insulators in the open position, and are capable of interrupting short-circuit currents that may be orders of magnitude larger than the normal current they carry.

The inner life of circuit breakers is complex and is best described by plasma physics and hot gas dynamics. Using 3-D multiphysics field simulations and purpose-designed high-power experiments, ABB Corporate Research in Switzerland is at the forefront of fundamental science in this domain. However, the work of corporate research does not stop there: The impact of findings on product performance is always analyzed, new concepts are proposed, simulated and tested, and proof-of-concept prototypes are built. With the support of corporate research, ABB has achieved a significant number of power engineering milestones over the years.

Invented at the ABB Corporate Research Center in Switzerland, the self-blast breaker uses the energy of the short-circuit current to build up pressure, drive a gas flow, and extinguish the hot arc plasma.

ABB Corporate Research Center Switzerland
Innovation highlights from our history.



1973
Self-blast circuit breaker for high-voltage switchgear

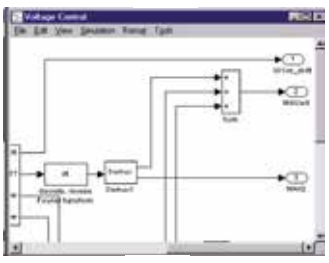
2001
Electronic gas meter

1975
Metal oxide surge arrester made from sintered ceramic material

2000
190 kA generator circuit breaker

1984
Super-twisted liquid crystal display (LCD)

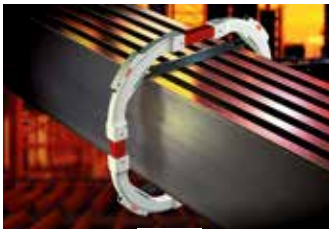
1996
High-temperature superconducting current limiter



1992
Graphical software engineering

1994
Presspack semi-conductor module for high-voltage direct current power transmission

2003
Wide-area protection for high-voltage grids



2004
Optical direct current sensor

2007
6.5 kV power module for traction

2008
Generator circuit breaker with heat pipe cooling

2017
Full SiC power module LinPak

2015
170 kV ecoGIS

2014
525 kV HVDC Cable

2012
PE Traction Transformer