PERPETUAL PIONEERING

Fifty years of ABB Corporate Research in Switzerland

In 1967, ABB established a research facility with a team of 34 scientists in Baden-Dättwil, Switzerland. In the fifty years since, the Swiss arm of ABB Corporate Research has grown significantly in size →1 and has produced a stream of fundamental breakthroughs and innovative product technologies.

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Special thanks are given to the many authors whose writings over the past 50 years have contributed directly and indirectly to the material presented here.

In 1891, Charles Brown and Walter Boveri created a start-up in Baden, Switzerland, to tap the opportunities of a promising new technology: electricity. Along with Asea, in Sweden, Brown Boveri & Cie. (BBC) was one of the precursors of ABB. Thanks to the vision and entrepreneurial spirit of its founders, BBC quickly became a success, pioneering many innovations that power the modern world. For the first decade or so, BBC's R&D was performed by the teams developing the products. However, in 1900, it was decided to create, in Baden, a distinct research labaoratory for steam turbines. Further acceleration in scientific advances necessitated the creation of a physics laboratory (1916) and a laboratory for high-voltage (HV) products (1943), both also in Baden.

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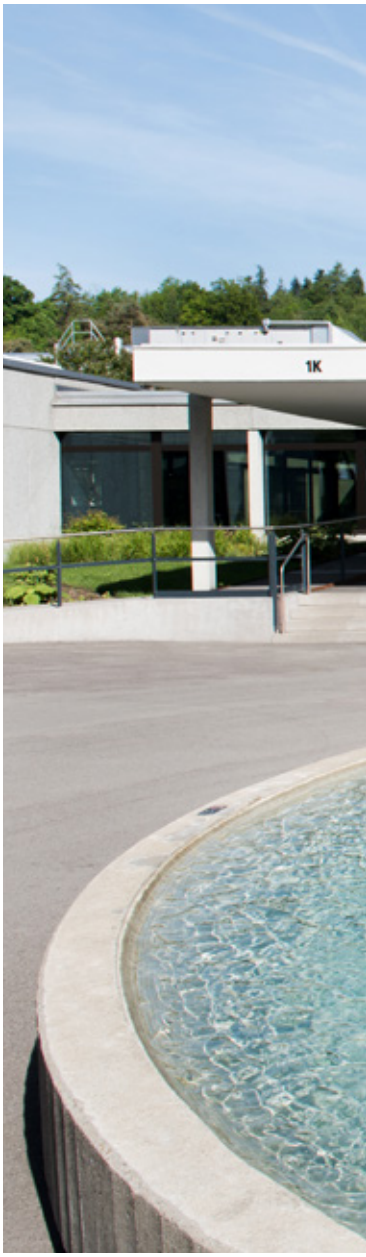

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01 The entrance to the ABB Corporate Research Center in Baden-Dättwil.

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02 Prof. Ambros P. Speiser (1922 – 2003), the first BBC Corporate Research Director.

In 1957, the now-famous “Zentrallabor” in Baden was founded. From this establishment flowed a prodigious number of innovations for power and industrial applications, many of which are still evident in the technology of today. Recognizing that all basic technical innovations come from the basic sciences and that it was important for the company to contribute to this creation process as a whole, plans were made in 1966 to found a Group corporate research organization.

To this end, Professor Ambros P. Speiser was recruited as the very first Research Director and given the task of establishing the Corporate Research Center in 1967 →2.

Ambros Speiser was the perfect candidate for the job. A graduate of the ETH in Zurich, his academic career had included Harvard, Princeton, and pioneering work with Rutishauser and Stiefel on the first generation of electronic computers. ERMETH, the first Swiss electronic computer, was developed under his leadership. Ambros Speiser established, and served as director of, the IBM Research Lab in Rüschlikon, Switzerland, which later won two Nobel prizes: in 1986 (scanning tunneling microscope) and 1987 (high-temperature superconductivity).

ABB Corporate Research Switzerland Highlights

1980 – 2017

HV circuit breaker with self-blast principle

1970 to 1975: Fundamental investigations to quantitively understand the arc and develop new diagnostic methods. From this work emerged a deep understanding, new concepts and an international reputation that survives to this day. The self-blast principle was born as a result of this activity and further investigated between 1975 and 1980. At first, the movement of the arc by magnetic forces was exploited and employed in BBC's MV products (1977). It was discovered that the self-blast principle can be used for HV circuit breakers by exploiting the ablation of PTFE nozzles for HV circuit breakers (CBs).

1980
Technology evaluation, followed by tests from 1981 to 1985.

1985
First product: CB for 72.5 kV and 25 kA short-circuit current.

2017
The properties of plasma arcs are nowadays studied with spectroscopy and high-speed imaging. 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 → picture (High-voltage experimental setup). The self-blast principle is still the most widely used concept by all manufacturers of HV CBs.

A time of great change

The Swiss Corporate Research Center was founded at a time when the world was entering a completely new technological era →3. Just a couple of years earlier, the first widely-used analog integrated circuit was introduced, by Fairchild; the developers could scarcely have guessed at the impact their invention would have in the coming decades. The race to the moon was in full swing – a mission which itself would result in major technology spin-offs. Nuclear power was booming. Color TV was introduced in many European countries for the first time. And at this time, BBC was a technology leader in energy production, transmission and distribution, plus many other areas. It was, indeed, an auspicious time to open a new research center.

Basic research as a mission

The remit of the research center focused on development and execution of a mid- to long-term research program in basic sciences that was measured not only by practical applicability

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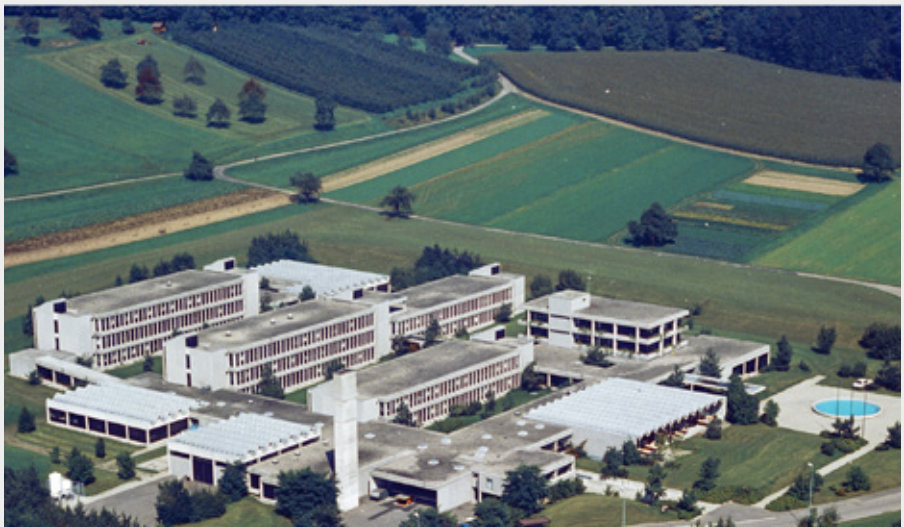

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1990 – 2017

Eco-efficient gas-insulated switchgear (HV and MV)

Though widely used in gas-insulated switchgear (GIS), sulfur hexafluoride (SF_6) is a potent greenhouse gas. ABB is the first company to offer MV GIS with a climate-friendly insulation gas based on a new molecule. ABB Corporate Research in Switzerland made a major contribution to this technology leap by evaluating the compatibility of the new insulation gas with the material components in the GIS under various operating conditions.

1990s
Extensive screening and testing of SF_6 replacement gases.

2008 – 2012
Combined corporate research and business area R&D effort toward the development of a CO_2-based HV CB.

2009
3M develops fluorinated ketones for use as a component of eco-efficient dielectric gas mixtures.

2009 – 2015
R&D on dielectric and physical properties and material compatibility of ketone-based mixtures.

2015
Inauguration of Oerlikon substation for ewz (Zurich) – first substation with eco-efficient switchgear (MV and HV).

2016
Product releases of compact SF_6-free MV switchgear – SafeRing AirPlus™ and ZX2 AirPlus.

2017
Further scouting for eco-efficient solutions with higher performance.
→ picture (SafePlus AirPlus SF_6-free switchgear).

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03 ABB Corporate Research Center

03a 1972, the new green-field site on the outskirts of Baden. The original 1967 team were temporarily housed in the area while the new complex was constructed.

03b 2015, the ABB complex in Baden-Dättwil has been expanded and other buildings have sprung up around it.

but also scientific importance. Promising developments were passed to the business units for productization. Over the first decades, the range of topics of interest grew:

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In 1973, the BBC research laboratories in Germany and France were integrated into the global BBC corporate research organization.

1967: Laser optical measurements, silicon carbide (taken over from the “Zentrallabor”)
1968: Plasma physics, magnetism, physical metallurgy, theoretical physics
1969: Semiconductors
1970: Automation and liquid crystal displays
1973: Fracture mechanics
1974: Fluid mechanics
1979: Electrochemistry and sintered materials
1980: Computer science
1984: Electromagnetic compatibility, communications and encryption
1985: Manufacturing technologies, optoelectronics and environmental technologies
1986: Microelectronics and robotics

In 1973, the BBC research laboratories in Heidelberg, Germany and CERCEM Le Bourget, France were integrated into the global BBC corporate research organization. An even more dramatic change came in 1988 with the fusion of Asea and BBC to become ABB (Asea Brown Boveri).

1967 – 2017

Metal-oxide (MO) surge arresters (varistors)

Properly rated and well-located surge arresters – such as the ABB Polim series – are essential in power networks to limit excessive overvoltages. Thanks to work done by ABB Corporate Research Switzerland, ABB has the full MO surge arrester value chain in-house – from raw material to finished product.

1967
Discovery of ZnO varistor effect at Matsushita by accident.

1972
GE takes license from Matsushita for low-voltage (LV) MO varistors.

1976
ABB Corporate Research Switzerland demonstrates its own HV MO varistors but BBC hesitates to enter production.

1976
ASEA buys technology from Matsushita and starts production.

1980
ASEA offers full range of MO HV surge arresters.

1982 – 1987
BBC ramps up varistor and arrester production, based on fundamental work done in ABB Corporate Research Switzerland.

1984
BBC pioneered polymer-insulated surge arrester for MV distribution.

1988
BBC and ASEA join forces and become world market leader for MO arresters in MV, HV-AIS/GIS, AC/DC, UHV, railway, etc., → picture (From 2001, an early suspension line insulator-arrester of type POLIM-S in which the mechanical support function and the surge protection are combined in the same device).

1988
Start of joint Swiss/Swedish R&D on MO technology.

2011
ABB high-field MO varistors for compact GIS.

2017
Continuing research and product development for new power electronics applications.

This led to coordinated management programs for the 800+ scientists in the now six corporate research centers in Switzerland, Sweden, Germany, Norway, Finland and Italy. At this time too, the role of corporate research was redefined to lessen somewhat the focus on basic science and bring activities closer to the business units and markets.

The role of corporate research was redefined to bring activities closer to the business units and markets.

This shift defines the research programs carried out by the research center in Switzerland today.

Today's research areas
The ABB Corporate Research Center in Switzerland employs about 200 employees from more than 35 different countries who focus on automation, power electronics, energy and materials, and power products and systems. The following sections give a flavor of some research topics in these areas.

Automation
Industry is now moving to the next level of automation systems, which not only execute simple control loops or rule-based processes but also 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™.

1968 – 1984

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Liquid crystal displays (LCDs)

1968
RCA presents first results on dynamic scattering LCDs.

1969
BBC makes a strategic decision to enter medical electronics market.

1969 – 1972
Collaboration with Hoffmann-La Roche.

1970
Hoffmann-La Roche: Twisted Nematic (TN) LCD.

1973
World's first LCD watch presented at MUBA consumer show, Basel. A joint effort of Hoffman-La Roche (liquid crystal material), BBC (LCD), Faselec (integrated circuit) and Ebauches (watch).

1973
LCD pilot production line in vacuum tube factory in Birr.

1974
LCD factory in Lenzburg, 110 employees, displays for Casio (Casiotron) and Swiss watch makers.

1978
Assembly line in Hong Kong.

1980
Videlec, BBC/Philips joint venture.

1983
Discovery of supertwist nematic (STN) effect, patent 12.3.1983. High resolution, excellent contrast, low power → picture (Passive matrix STN LCD, 540 × 270 Pixels).

1984
Videlec sold to Philips, research team refocused on optoelectronics.

1984
BBC decided to keep STN LCD patent, very lucrative license revenue stream.

ABB Ability digitalizes industrial automation
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 turn 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. ABB is a leading manufacturer of field instruments and ABB Corporate Research in Switzerland contributes to these products with research in optics, laser spectroscopy, radar applications and acoustics. Researchers also focus on the embedded computations needed to run advanced control algorithms that solve challenging optimization problems in real time.

System architecture
With systems becoming smarter and more digital, their inherent complexity increases. How, then, can one build systems that are correct, dependable, scalable, secure, safe

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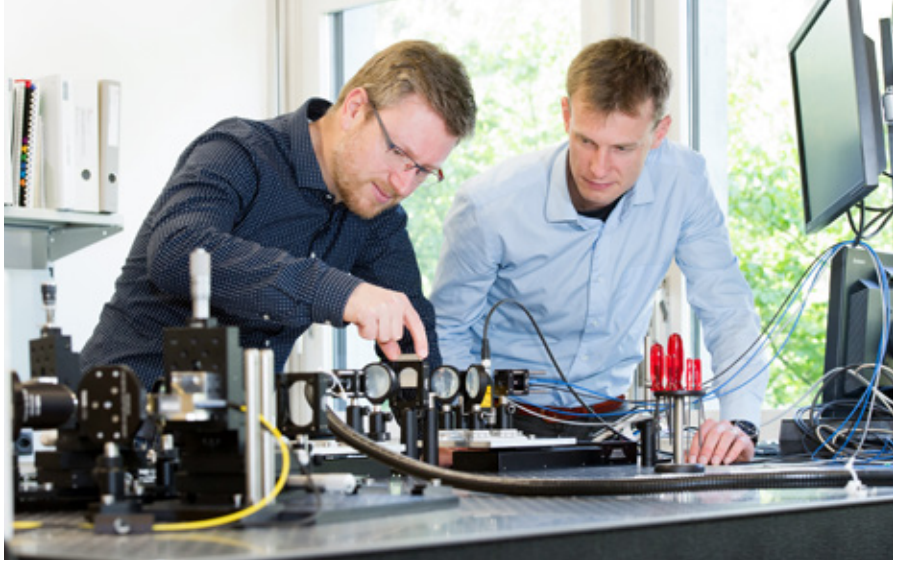
and that deliver high performance? To answer these, and other, questions, ABB Corporate Research is developing the next generations of software and systems architecture.



1970 – 2016

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Fiber optic current sensor (FOCS)

Circa 1970
Research on early Faraday-effect devices, abandoned.

1992
Fundamental ABB patent on modern FOCS, Ph.D. thesis.

1997 – 2001
Basic FOCS development, FOCS demonstrated in 170 kV circuit breaker at ENEL substation.

2000
ABB in the United States launches magneto-optic current transformer (MOCT).

2005
Product launch – FOCS for industrial DC. Finalists of the Swiss Technology Award and Hermes Award (Hannover Fair). FOCS production starts in Baden-Dättwil.

2007
Produced 100th FOCS; FOCS production moved from Baden-Dättwil to Turgi, Switzerland.

2006 – 2008
FOCS second-generation (G2) technology developed: IEC 61850-9-2-compliant ABB electronics.

2009
FOCS G2 product development starts.

2010
Pilot installation of live tank CB with FOCS at Swedish National Grid.

2016
First commercial disconnecting CB with FOCS installed at a State Grid China Corporation (SGCC) next-generation smart substation → picture (Physicists work on new developments in the optics laboratory).

Increasing computational power and the adaptation of general-purpose operating systems enable more applications to exploit real-time monitoring and control. ABB Corporate Research in Switzerland focuses on several aspects of real-time systems to provide corresponding solutions, including system architectures, dependable digital communication and real-time test systems.

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The revolutionary approach of homomorphic encryption allows sensitive data to be encrypted and sent for analysis without sharing a decryption key.

Security and privacy for cyber-physical systems
Customers demand that their data is treated securely. The revolutionary approach of homomorphic encryption allows sensitive data to be encrypted and sent for analysis without sharing a decryption key. Only the customer can access the data and results. ABB Corporate Research has found ways to massively reduce the computational overhead of homomorphic encryption, thus making it usable in an effective way.

Blockchain is another technology that helps to establish secure transactions between parties that do not trust each other. Researchers are 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.

1988 – 2016

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Power electronics: semiconductors, packaging, integration, converters and control

Power electronics is a core competence of ABB Corporate Research in Switzerland. A key asset is the PEARL (Power Electronics Advanced Research Lab) facility, which enables research into next-generation power semiconductors, modules and applications. New devices are designed in-house, then samples are fabricated in the lab's cleanroom. The semiconductor dies can then be packaged and integrated into larger power modules. The "Mikrolabor" was an earlier semiconductor manufacturing facility for applied R&D of power electronic devices.

1988 – 1994
Period of the "Mikrolabor."

1988 – 1994
Field-controlled thyristor (FCTh) R&D forms the basis of the IGCT (integrated gate-commutated thyristor).

1988 – 1994
MOS-controlled thyristor (MCT) R&D enables the ABB IGBT.

1995 – 1998
IGBT production transferred to an external company.

1995
100 MW IGCT-based PCS power converter.

1995 – 2000
IGBT-based Flatpack and StakPak power modules.

1998
IGBT production transferred from external company to the ABB semiconductor factory in Lenzburg, Switzerland.

1999
ACS6000 5 – 30 MVA drive (IGCT).

2010
4.5 kV StakPak modules for HVDC Light.

2014
The new PEARL, → picture (PEARL state-of-the-art facilities for advanced packaging) is opened.

2016
STATCOM (static synchronous compensator) based on a new topology and improved IGCT.

Power electronics
Where high voltages and currents have to be controlled, power electronic devices are to be found. 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 the new PEARL 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.

SiC developments
Silicon carbide (SiC) semiconductors have many advantages over silicon-based devices. ABB Corporate Research in Switzerland has long experience in, and a fundamental understanding of, the science of SiC. To exploit the benefits of SiC, researchers are developing SiC devices, such as Schottky diodes and MOSFET switches, that can be used in ABB 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 Corporate Research in Switzerland is

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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.

1996 – 2017

High-temperature superconductivity

With the high-temperature superconductivity (HTS) Nobel success at Prof. Speiser's IBM laboratory in Rüschlikon, it was inevitable that the subject would become one of interest for ABB Corporate Research and one in which notable successes would be scored.

1986
Discovery of high-temperature superconductivity at IBM; Nobel Prize in 1987.

1996
ABB Corporate Research, Switzerland: 12 MW fault-current limiter (FCL) pilot project based on HTS materials installed in Switzerland (first HTS FCL in grid).

1997
630 kVA (18.7/0.42 kV) transformer using superconductive wire at SIG in Geneva (first HTS transformer in grid).

2002
6.4 MVA resistive FCL passes laboratory test.

2001 – 13
Collaboration with University of Geneva on a superconductive FCL.

2012 –17
Single-phase 577 kVA (20/1 kV) current-limiting transformer test device using superconductive wire in collaboration with Karlsruhe Institute of Technology (KIT) shown at Hannover Fair 2017 (by KIT) → picture (Collaboration with KIT: current-limiting transformer using superconductive wire (test device)).

04 Multidisciplinary teams at ABB Corporate Research investigate the fundamental principles of power systems.

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, which is currently employed in drives, photovoltaic inverters and dry transformers.

Involvement in energy and materials ranges from fundamental understanding to advanced material development and process technologies.

1996 – 2017

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Automation

**Substation Automation –
The ecosystem around the
IEC 61850 standard series**
The IEC 61850 standard is the enabler for the digital substation. Since its early days, ABB Corporate Research has provided key contributions to both the standard itself and ABB's implementation of the technologies and tools:

- Key contributions to all aspects of the standard and the engineering guidance documents as members of the IEC technical committees and working groups (eg, IEC TC57)
- Systematic modelling in UML of the standard to drive automatic software generation and documentation (eg, ABB 61850 base libraries)
- Concepts and architecture for substation automation engineering, testing and commissioning tools (eg, ITT, IET and DST600)

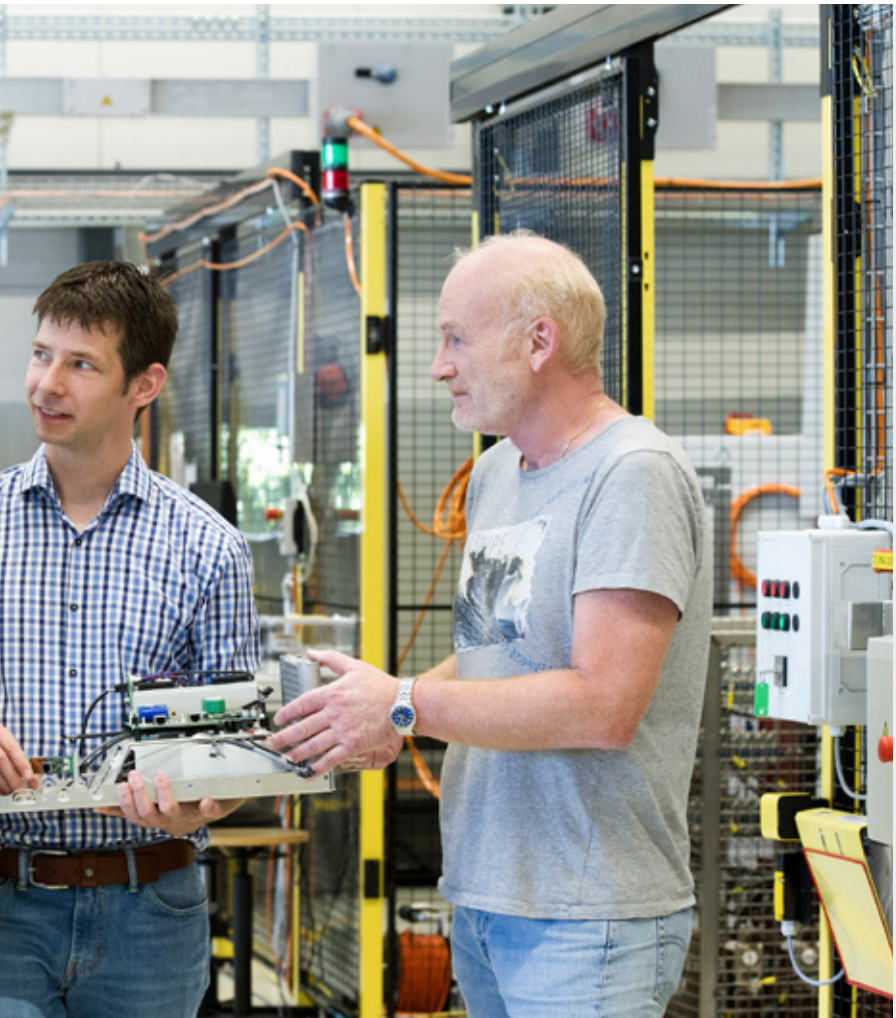
Railway communication and control technology
Corporate Research in Switzerland has a history of key technology contributions for railway applications:

- TCN (train communication network) is used on trains worldwide.
- ETCS (European train control system) – significant contributions
- Adhesion control for sensorless traction chains were pioneered
- Remote diagnosis for trains (ROSIN) established
- Electrical systems Compatibility for railway vehicles

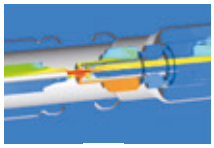
Automation – always leaders
ABB Corporate Research has always been a pioneer in information and communications technology:

- Procontrol P215 as common control platform for BBC
- Pioneered graphical software engineering in 1992 with "FuPla", leading to CoDeSys and IEC 61131 as groundbreaking innovations
- Error-tolerant processors enabling Pacific intertie HVDC project
- WISA concept for wireless sensors and control in factories winning Gold Award for Technology Innovation by the Wall Street Journal
- GLASS – remote monitoring of embedded systems using internet technologies as a precursor of the Industrial Internet of Things
- Identified the need for and pioneered robust industrial cyber security years before 9/11 and Stuxnet. Later, secure data storage and computation in the cloud

LEAP – LEarning for PlAnt Process Improvement
- Explore emerging machine learning technologies for automatic model generation and decision making within advanced process control
- Provide the missing pieces: accountability, robustness, maintainability
- Machine Learning expected to be a game changer
- Improve engineering efficiency and facilitate development of advanced control solutions



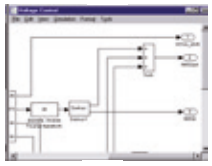
Energy and materials
ABB Corporate Research's involvement in energy and materials ranges from fundamental and first-principle understanding to advanced work on material development and process technologies. In the physics domain, for example, the first-principle understanding of charge transport in HV 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, researchers in Switzerland help optimize thermal management to improve power ratings and product footprints.



1973
Self-blast circuit breaker for high-voltage switchgear

1975
Metal-oxide surge arrester made from sintered ceramic material

1984
Super-twisted liquid crystal display (LCD)



1992
Graphical software engineering

2001
Electronic gas meter

2000
190 kA generator circuit breaker

1996
High-temperature superconducting current limiter

1994
Presspack semiconductor module for high-voltage direct current power transmission

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.

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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.

Activities in material research and manufacturing methods include the development of novel metallic compounds as high-performance contact materials in circuit breakers; the development of hard permanent magnets by innovative methods such as 3-D metal printing and spark plasma sintering; and new material concepts based on thermoplastics, thermosets and elastomers together with novel manufacturing processes for bushings that are completely oil- and paper-free.

Power products and 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 →4. The Power Systems of the Future research program, for example, 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.

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— 05 Some of the significant breakthroughs that emerged from ABB Corporate Research in Switzerland, 1973 to 2017.

Thus, potential technical challenges can be evaluated, such as the increasing need for adequate operating reserves and transmission or distribution feeder capacity, reduced system inertia and short-circuit capacity.

Increased electric power transmission distances have led to significant penetration of embedded HVDC into existing AC transmission grids worldwide. Swiss researchers have developed novel control schemes to exploit HVDC capabilities and thus maximize overall grid transfer capacity.

The next 50 years

The 34 scientists who signed up to the embryonic ABB Corporate Research in Switzerland in 1967 could scarcely have envisaged that their efforts would lay the foundation for so many significant and successful ABB technologies →5.

They could certainly never have predicted how the world of technology in general would change over the next five decades.

Now, when technological change is more rapid than at any time in human history, it is almost impossible to imagine what technologies will exist in 2067, a further 50 years hence. What is certain, though, is that the pioneering, inquisitive and inventive nature of a whole new generation of ABB Corporate Research scientists will be there to write the future. ●