125 years and a centennial

ABB celebrates 125 years' existence in Switzerland and 100 years of corporate research

DOMINIC SIEGRIST – 2016 is a momentous year for ABB. Not only does it mark 125 years since the birth of Brown Boveri & Cie. (BBC) Switzerland, but it also sees the centenary of ASEA's corporate research organization in Sweden. Over those years, an astounding amount of technological progress has been made by BBC and ASEA – both separately and together (since 1988) as ABB. There will be celebratory events around the globe and some of the more important advances will be described in detail in this and subsequent editions of ABB Review. It is worth taking a brief look at some of the technical highlights of BBC over the past 125 years and some technical achievements of the Swedish research organization in the past decade.

Title picture
Size was no obstacle to BBC and ASEA. Shown is a BBC 2 MW three-phase AC generator in a German steelwork, in 1912.

"Power and automation for a better world™" is the ABB corporate motto. Even in the earliest days, the products developed by ABB's main constituent companies reflected the ethos expressed by this maxim.

In 1883, ASEA was founded in Västerås, Sweden, by Ludvig Fredholm. ASEA's very first products – for electric light and generators – very much contributed to a better world. Similarly, when, in 1891, Charles Brown and Walter Boveri created Brown Boveri & Cie. in Baden, Switzerland, their electrical products facilitated major improvements in the lives of many millions. Indeed, by making the widespread use of a brand-new resource – electricity – possible, the products developed by these two progenitors of ABB made a major contribution to the greatest technological change society had ever seen → 1.

BBC technological breakthroughs came rapidly: In 1891, the first power station in the town of Baden was built; in 1895, the tram system in the Swiss city of Lugano was provided with electrical equipment → 2; in 1897, there came the first of many high-voltage oil circuit breakers → 3; and by 1911, the company had developed an electrically powered locomotive that ushered in a new era of railway electrification. In fact, locomotives formed a significant part of BBC's research and development effort right up until the end of the 19th century.

In 1905, BBC suggested to the SBB (the Swiss national rail operator) that the Simplon Tunnel, then under construction, should be electrified. The SBB declined and BBC offered to do the job at its own cost. Although not a financial success, the project resulted in the world's first international electrified train link and the experience gained gave BBC's railway electrification business a massive boost, as was evident by the many contracts won in the subsequent years, including the huge order for the Gotthard Tunnel some 15 years later → 4.

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ASEA and ABB products facilitated major improvements in the lives of many millions.

1 Walter Boveri, accompanied by his wife (middle) and an acquaintance, inspecting the construction of the first factory building, 1891.

Between the wars

The period 1918–1939 proved to be stormy. After a worker and raw material shortage during World War One, BBC experienced a short boom up until 1920, when there was nearly a complete collapse in orders for some years. The subsequent recovery was short lived as the Wall Street Crash of 1929 wreaked further havoc. Once again, however, the business bounced back and in 1939 the first shareholder dividends for seven years were paid out.

BBC – war and expansion 1939 to 1970

In 1936, BBC had become a late entrant to the radio market but succeeded in quickly establishing itself, with its first transmitter valve appearing in 1939. Valve production was moved from the laboratory to a specially constructed factory in 1943. Valve technology gradually expanded from purely radio transmission to heat generation for industrial applications and radiotherapy. This was to culminate in the development of a clinical electron accelerator (Betatron) by the end of the decade.

In 1939, BBC built the world's first gas turbine, which served the town of Neuenburg as an emergency generator until as recently as 2002. It now adorns the pavilion of the ALSTOM works in Birr, Switzerland as a proud reminder of BBC's history.

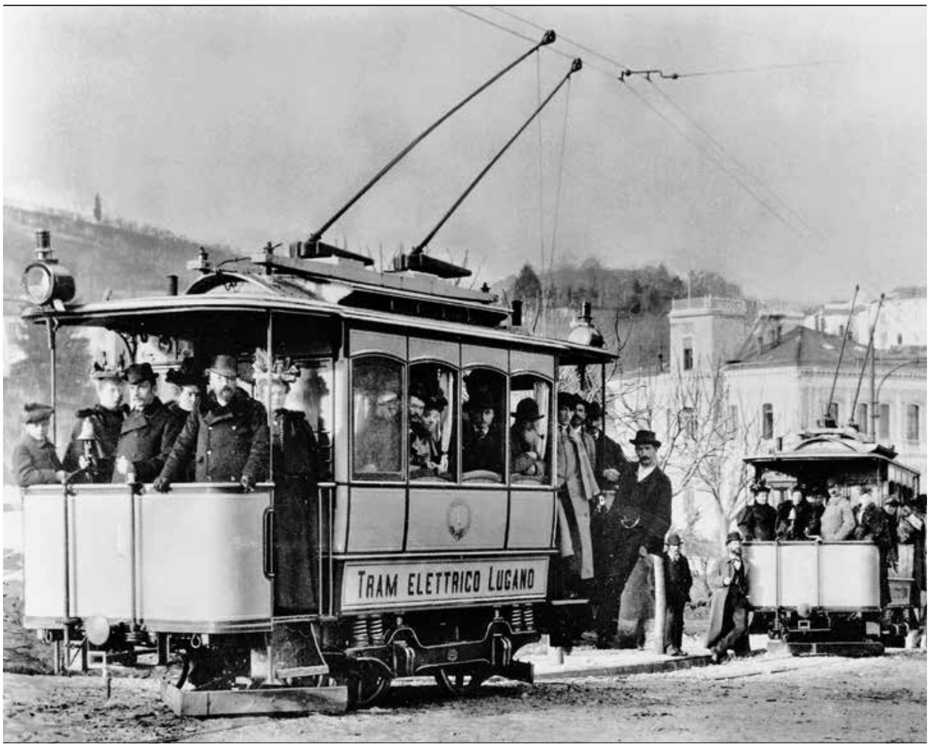
The outbreak of World War Two threw the company into renewed turmoil. Once again, there was a shortage of workers due to military conscription, even as orders grew. The company found itself in a delicate situation, supplying both the allies and the Third Reich. However, home orders rose to record levels (40 percent of all orders were delivered to Swiss customers in 1942/43) – especially in power generation products. Moreover, Spain, rebuilding after the civil war, became one of BBC's largest customers. In the midst of World War Two, the company managed to find the resources and time to build the high-voltage laboratory in Baden – a facility that was to prove invaluable in years to come.

By 1935, BBC in Mannheim, Germany, had grown to dominate the original site in Baden. Business flourished with orders for war material: U-boat drives, warship turbines, jet engine compressors, etc., but heavy bomb damage in 1944 subdued activity, though the company was flourishing again within ten years' of war's end.

Toward the end of World War Two, orders exceeded capacity and when the war ended in 1945, the company found itself in a favorable business position as most divisions expanded. The mid-1950s saw a boom in steam turbines, with systems of unprecedented power and massive orders from customers such as the Tennessee Valley Authority (who were to receive a record-beating 1,300 MW BBC turbogenerator in 1967). Turbochargers saw similar growth – both in business volume and technical capability.

In 1953, BBC's specialized laboratory for aerodynamics and combustion research was opened. 1965 saw BBC bring out the world's first water-cooled hydro-

2 BBC supplied much of the electrical equipment for the electric tram system in Lugano at the end of the 19th century.



The Simplon electrification was the world's first international electrified train link and the experience gained gave BBC's railway electrification business a massive boost.

generator. On the domestic front, BBC produced cookers, washing machines, humidifiers and bed warmers – this business arm was sold to AEG in 1972 (though BBC continued to make coffee machines until the 1980s).

Like the BBC story above, ASEA also has a history studded with technical breakthroughs. In this, the 100th anniversary of the founding of the ASEA's corporate research arm, it is worthwhile to look back at some of the momentous products that the organization has produced in the past decade or so.

Driving progress

By the late 1960s, the pace and breadth of both ASEA and BBC's technological progress had increased significantly and advances in electronics were opening up entirely new ways to approach industrial problems. An early example of the benefits delivered by electronics was the digital variable-speed drive (VSD).

Electric motors are ubiquitous in industry. In fact, about two-thirds of all the electrical energy produced in the world is converted into mechanical energy by electric motors. The vast majority of these motors are used to power fans, pumps and compressors. Most of these applications operate at constant speed, all the time, even when not needed, using throttles or valves to control the flow of fluids or gases. This represents a huge waste of energy.

Enter the VSD. Launched in 1969, and equipped with a revolutionary technology called direct torque control (DTC), VSDs adapt the speed and torque of the motor according to the precise needs of the application. Typically, energy savings of around 50 percent can be achieved and control quality improves.

In 2011, ABB made another significant step in motor technology with its synchronous reluctance motor (SynRM).

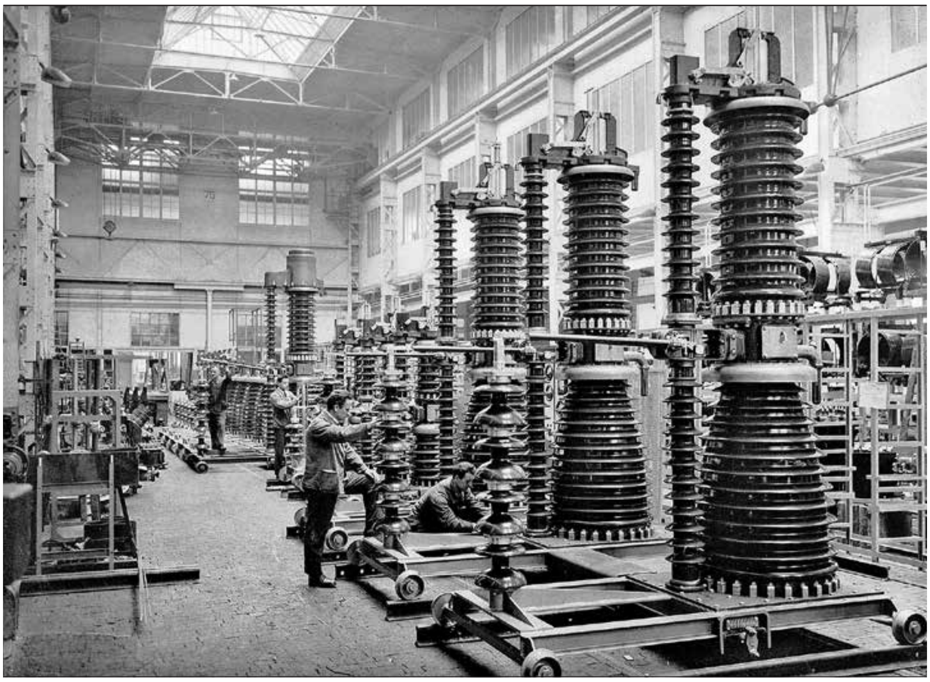
SynRM

Induction motors (IMs) are by far the most common motors in industry. This powerful and efficient motor does not have a commutator or brushes, which makes it reliable and relatively maintenance-free. However, it has certain drawbacks, which can be overcome by the permanent magnet (PM) AC motor.

PM motors only became competitors to IMs in the 1980s with the creation of a new generation of permanent magnets based on rare-earth elements (REEs) such as neodymium iron boron (NdFeB). (Note that such motors need sophisti-

In 1967, the Tennessee Valley Authority took delivery of a record-beating 1,300 MW BBC turbogenerator.

3 High-voltage switch manufacture in 1935



cated AC drives – another area of ABB innovation.) The PM motor is synchronous, meaning the rotor rotates in synchronism with the magnetic field. This offers more precise speed control, higher efficiency, lower rotor/bearing temperature and a host of other advantages.

There is, of course, a catch: REEs are costly and can be subject to price variations. In addition, their strong magnetic rotor field can make servicing more difficult.

In recent years, ABB introduced two REE-free motors – SynRm ➔ 5 and the permanent-magnet-assisted synchronous reluctance motor (SynRM2, introduced in 2014), which use ferrite magnets.

SynRMs perform better than conventional IMs. They can be designed for high-efficiency performance or to provide a higher power density for a smaller footprint than an equivalent IM. They need less maintenance, have a reduced inertia and are extremely reliable.

Softstarters

One of the drawbacks of the IMs mentioned above is the problem of starting them. The most common starting method is the direct-on-line (DOL) start using a main contactor and a thermal overload relay. Unfortunately, this leads to a starting current that can be six or seven times the rated current.

Just over 30 years ago, ABB introduced the softstarter. A softstarter reduces the torque to the electric motor as it starts. This reduces voltage drops on networks, minimizes starting currents, eliminates current spikes and allows cabling to be optimized.

In the intervening years, ABB has refined the softstarter concept with new models continually released to the market. 2010 saw the introduction of the very successful PSE model; in 2014 the PSTX offered new communication features and a new operator interface that gives diagnostic information.

The direct approach

Around the same time that ASEA and BBC came into existence, the War of Currents was taking place. This pitted Edison’s established direct current (DC) technology against the new alternating current

An early example of the benefits delivered by electronics was the digital variable-speed drive.

4 A novelty in 1919: An electric locomotive for the Gotthard Tunnel line on a test drive at Thun, Switzerland.

(AC) approach championed by, among others, Westinghouse (later part of ABB). Initially, because it was more efficient to transmit and easier to handle, DC was the standard method of medium-voltage (MV) power distribution. However, AC technology soon came to dominate.

Recent technical advances – especially in semiconductor technology – have allowed DC back onto the stage. This factor, coupled with the need to shift vast quantities of electrical power around the globe, provided a significant driver for ABB to introduce high-voltage DC (HVDC) technology, the key technology of which is the series connection of insulated-gate bipolar transistor (IGBT) press-packs.

The power needed to control an IGBT is very low and can be taken from the snubber circuit connected in parallel with the IGBT. Therefore, no auxiliary power from ground level is needed. Moreover, the device's gate unit can very precisely turn the IGBT off and on, thus making it possible to connect the IGBTs in series and control hundreds of IGBTs individually in a fraction of a microsecond.

This technology formed the basis of HVDC Light, launched in May 1997, based on two-level converters working up to around +/– 80 kV. Nineteen years after the first tentative steps, ABB's HVDC Light is a billion-dollar business with 25 HVDC Light installations around the world, transferring over 10 GW.

Transformers

ABB has been a leader in transformer technology for many decades. The most recent advances are in the area of ultra-HVDC, with power transformers rated at up to 1,100 kV.

A transformer often has to have a tap changer and this is another pioneering field for ABB that has continued to see constant progress over the years. ABB's newest vacuum on-load tap changers reduce maintenance requirements and improve performance by ensuring that the electrical arcing that previously took place in the insulating oil now takes place in a vacuum interrupter, thus preventing arcing from contaminating the oil.

HVDC cables

HVDC power is not only carried by overhead transmission lines, it is also carried by cables – for example, to bring power from offshore wind farms or to link national grids across a sea. The practical length of AC cables is limited by capacitive effects, so the future of long-distance power transmission lies with HVDC technology. Over the last 30 years, ABB has made significant technical progress in HVDC cables – for instance, with a 525 kV extruded cable system, launched in 2014, that is based on high-quality cross-linked polyethylene (XLPE). ABB has also developed a dynamic cable structure for HVDC – especially useful for offshore platforms.

Hybrid breakers

HVDC systems have to be disconnected if a fault arises. Today's HVDC installations are mostly point-to-point and can be disconnected by AC breakers at each end. However, this means the entire line is dropped. Once HVDC grids become commonplace, a fault could cause the entire grid to be dropped. A further complication is that disconnection has to happen much more quickly in a HVDC system than in a corresponding AC system.

These factors provided the motivation for ABB to develop its hybrid breaker. Once again, the benefits of power semiconductors were exploited: The ABB hybrid circuit breaker consists of a main breaker built of power electronic switches and surge arresters, and a parallel branch containing an ultrafast disconnector (UFD) and power electronic load commutating switch. This "hybrid" allows fast disconnection suitable for HVDC applications.

The power needed to control an IGBT is very low and can be taken from the snubber circuit connected in parallel with the IGBT.

Automation

Power is one pillar of ABB technology; automation is the other. It is no exaggeration to say that advances made by ABB changed the face of industrial automation. Not only did the company produce innovations in digital control systems (DCSs) and plant automation but ASEA was responsible for the world's first commercially successful electrical industrial robot, in 1973.

Early attempts at robotics by others, in the 1950s and 1960s, had resulted in clumsy, noisy, hydraulic beasts that

The key HVDC technology developed by ABB was the series connection of insulated-gate bipolar transistor (IGBT) press-packs.

5 The unique SynRM rotor

leaked copious amounts of oil. In the early 1970s, ASEA recognized the potential of electrically driven robots and proceeded to develop and market the world's first – the IRB 6 (Industrial RoBot/6 kg payload). As soon as it appeared, the IRB 6 was a success. The first order was to a small Swedish company and four of the five they ordered are still working in the same place, doing the same job, more than 40 years later – a testimony to the excellent design.

Following on from the IRB 6, whole new generations of ABB robots have been developed for automation tasks in many different industries.

Continued innovation all around the world

ABB's power and automation technology has been inspired by challenges in all possible spheres – in homes and offices, oil and gas fields in remote deserts, water treatment plants, underground in mines, deep beneath the sea (with transformers that work at depths of 3,000 m, for instance), in crowded, cramped cities, in fields and in manufacturing and processing plants that have changed beyond all recognition in recent years. ABB technology is even circling the globe in a satellite.

A significant new area of challenge – one that would not have been foreseen by Brown, Boveri or Fredholm – is climate change. The intellectual energy now being devoted toward mitigating anthropogenic effects on climate has created entirely new areas of innovation for ABB.

Renewable energy is one such area. Wind, solar, biomass, and other forms of generation have challenged ABB to come up with power and automation solutions.

In addition to the generators themselves, distributed renewable power generation and its attendant technologies – such as microgrids, energy storage, load balancing, power conditioning, marketing, scheduling and so on – are other areas that have seen the effects of ABB innovation.

Since the merger of ASEA and BBC in 1988 to form ABB, the company has retained technology and market leadership in many areas by continued innovation in power and automation. Many of the benefits of modern life were made possible by the efforts of ABB researchers over the past 125 years.

125
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THE WORLD FROM
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