Powering the world's high-speed rail networks

The high-speed rail sector is undergoing huge and rapid growth. Widespread traffic congestion and concerns over carbon emissions are causing many countries to reassess their transportation policies and turn increasingly to rail. High-speed trains are particularly effective at taking pressure off short-haul flights and bringing cities closer together.

Today, Belgium, France, Germany, Italy, the Netherlands, Spain, the United Kingdom, China, Japan, Korea and Taiwan all have high-speed lines in operation. Many other countries, including Brazil, India, Morocco, Russia, Saudi Arabia and the United States, either have high-speed rail systems under construction or under development. Within the next few years, the world's high-speed rail network could quadruple from 10,739 kilometers in 2009 to around 42,000 km in 2020.

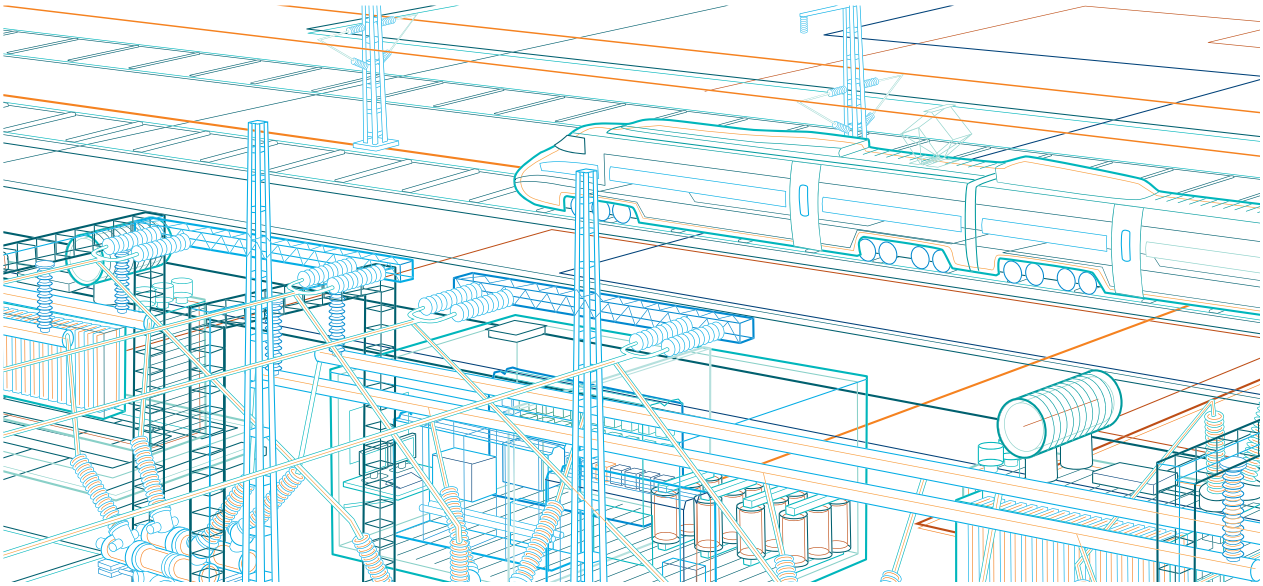
ABB is playing a major role in the development of the world's high-speed rail systems, providing cutting-edge power technologies and solutions for both railway infrastructure and high-speed rolling stock.

What is high-speed rail?
The International Union of Railways (UIC) defines high-speed rail travel as 250 km/h or more. Typical attributes of high-speed trains are:

- The use of trainsets rather than conventional locomotives and car formations. These offer better power-to-weight ratios, aerodynamic profiles, more space for the passenger, as well as reliability and safety.
- The use of dedicated high-speed lines on at least part of the journey. Such lines are built to sustain high speeds through the special design of transverse sections, track quality, catenary, power supply, and so on.
- And, the use of advanced signaling systems, including in-cab signaling.

High-speed rail electrical infrastructure
ABB is the world's leading supplier of traction power supply products and systems for the rail industry. We design, engineer, manufacture, install and commission a complete range of electrical technologies that ensure the efficient, reliable and safe supply of electric power to high-speed lines.

Our product portfolio includes traction substations that feed and distribute power to the lines; static



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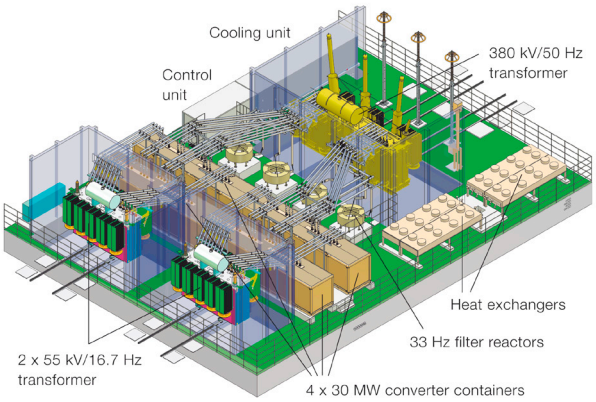
frequency converter stations that convert the power to the correct current and frequency; power quality systems that protect the network and the surrounding grid from voltage disturbance; network management and SCADA systems that monitor and control the rail and power distribution networks; and high-end expertise like system analysis and dynamic traction power supply simulations.

Among these many ABB technologies are three that are proving particularly beneficial for high-speed rail power supply.

Static frequency converters

Electric railways require huge amounts of energy. Many rail network operators run their own high voltage power grids, and some even operate their own dedicated power plants. Few railways are totally autonomous: they have to exchange power with the high voltage grid. For historical reasons, there are often significant differences between rail electrification networks and national power grids. Some rail networks use direct current (DC) rather than the alternating current (AC) of the grid; others operate at a different frequency or use only single phase compared to the three-phase power of the grid.

The technology that makes power exchange between grid and rail system possible is power conversion. In the past, rotary converters were used, but in recent years static frequency converters based on power electronics have replaced the old technology. ABB delivered the world's first railway static frequency converter in 1994. Today, there are more than 1,000 megawatts (MW) of static frequency converters in operation in rail networks, and an additional 800 MW on order. Many of these are in the 15-20 MW range. The world's largest and most powerful converter system is rated at a massive 413 MW, which ABB is currently delivering to the German network (see page 4 under 'Germany.')



One of the four ABB converter units that make up the world's most powerful converter system. Located in Germany, each unit has a rated power of 103 MW

FACTS for power quality

Modern traction systems present demanding challenges to power grids. Trains taking power from the catenary require stable supply voltages. Voltage and current imbalances need to be confined in magnitude and prevented from spreading throughout the grid. And voltage fluctuations and harmonics need to be controlled and kept within stipulated limits.

Power grids that feed railway systems and rail traction loads benefit enormously from flexible AC transmission system (FACTS) technologies like static var compensators (SVC) and the more recent SVC Light (also known as STATCOM – static synchronous compensator). These technologies were pioneered by ABB and provide an extensive range of benefits for rail systems and power grids, including dynamically balancing non-symmetrical loads, mitigating voltage fluctuations, eliminating harmonics, and providing power factor correction and dynamic voltage support. ABB FACTS solutions for high-speed rail are currently in operation in France, the United Kingdom and Australia.

Transformers for high-speed rail networks

More than 100,000 ABB vacuum cast coil dry-type transformers are currently in operation around the world today. Around 1,600 of these, with individual power rating of up to 16,000 kVA, are installed in rail networks, either for substation distribution or traction power supply. The latter application requires an especially robust technology. ABB's hi-T Plus transformers can operate at much higher temperatures (hence, hi-T Plus) and have a longer service life than conventional vacuum cast coil transformers, thanks to the use of materials with class H thermal insulation (the highest). This enables them to withstand strong overloads, high harmonic distortion and high unforeseen temperatures. High-speed rail networks in Spain and Switzerland are among those that rely on hi-T Plus technology (see 'Switzerland' and 'Spain' on pages 4 and 5 respectively).

High-speed rolling stock traction equipment

ABB is the world's leading supplier of electric propulsion technologies for high-speed rolling stock. We supply the traction transformers, traction converters and traction motors that power many of the world's high-speed trains, as well as the auxiliary converters that distribute the power to the train's onboard applications. Our high-speed rail portfolio includes a complete range of low voltage products, semiconductors, circuit breakers and surge arresters that feed, control and protect the train's onboard power distribution system.

ABB has strategic alliances for the development and supply of propulsion equipment with most of the

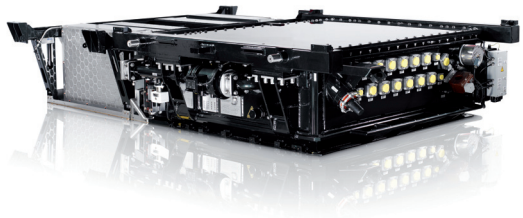
world's leading train manufacturers, including Alstom Transport, AnsaldoBreda, Bombardier Transportation, CAF, Siemens Mobility, Skoda, Stadler Rail and Talgo.

Traction transformers

ABB has been manufacturing traction transformers for over 100 years. More than half of the world's locomotives and trainsets are powered by ABB transformers, and the vast majority of the world's train manufacturers and rail operators rely on them.

The traction transformer is a key component of the train's onboard traction chain. Its function is to transfer electrical energy from the catenary to the motor by reducing the network's high voltage to low voltage (for example, from 25 kV AC to 750 V AC) for use by the converters. Traction transformers have to be compact, lightweight and exceptionally reliable, as they are often a non-duplicated traction component. And, in some parts of the world like Europe, they have to deal with multiple voltages and frequencies due to the different electrification systems in use in different countries or different parts of the same country.

ABB is supplying traction transformers for the high-speed trains of Alstom, AnsaldoBreda, Bombardier, CAF, Ministry of Railways China, Siemens Mobility and Talgo.



ABB's traction transformers are used in Siemen's Velaro high-speed platforms

Traction converters

ABB is one of the few independent suppliers of traction converters and complete traction chain packages for rail vehicles. The traction converter is the intelligent link between the power supply from the catenary and the traction transformer on the one hand, and the traction motors that power the vehicle on the other. It provides the exact voltage wave patterns for the traction motors to control their speed and torque and the energy flow to the wheels.

ABB traction converters are used onboard all types of rolling stock, including high-speed trains. One of the most impressive recent orders is a mid-life refurbishment solution for the power cars of Deutsche Bahn's ICE 1 high-speed trains. The solution delivered a raft of benefits for DB, including substantial reductions in energy consumption and operating costs (see 'Germany' on page 4).

Traction motors

The traction motor is an electric motor that powers the driving wheels of a railway vehicle. ABB has been manufacturing industrial motors for more than 130 years and traction motors for more than 100 years. Over recent decades ABB has delivered an estimated 30,000 traction motors for all types of rolling stock applications, including high-speed rail.

In 2010, ABB launched a new modular motor that is especially designed for high-speed and regional trains. Traditionally, traction motors are among the many custom-made components required by train manufacturers. These motors are intensely engineered, which impacts their cost, lead time and ease of maintenance. ABB's new 'one platform, multiple designs' concept overcomes these obstacles by meeting the diverse requirements of customers from a single modular platform. The motors are built to customer specifications by combining a set of standard components into a vast number of possible product configurations. They also feature a new electrical design that is optimized for high energy efficiency and a competitive performance/weight ratio.

ABB's new modular traction motor is designed for regional and high-speed trains

Traction package

The transformers, converters and motors that make up the propulsion systems are critical to the performance of high-speed rolling stock. Even though ABB is not a train manufacturer as such, ABB supplies complete traction packages that offer the best overall solution and optimization in terms of cost, reliability, weight, size and energy efficiency.

National high-speed rail networks

ABB is playing a significant role in the development of high-speed rail electrical infrastructure and rolling stock in most of the world's high-speed rail networks. Below is a country-by-country guide to how ABB solutions are supporting utilities, rail operators and train manufacturers in order to overcome the technical challenges of high-speed rail.

Germany

Germany has an extensive high-speed rail network, with links between major cities as well as to five of its neighboring countries: the Netherlands, Belgium, France, Switzerland and Austria.

ABB is currently delivering the world's largest rail converter station at Datteln in northern Germany. Ordered by E.ON, one of the world's largest energy companies, the 413 MW converter station will replace existing rotary converters that have reached the end of their operating life. The converter station will receive power at 50 Hz from a nearby power plant and feed it at 16.7 Hz into the 110 kV rail network. As the Datteln node is one of the most important supply points in the entire German rail network, a very high level of availability is vital to rail operations. The ABB solution consists of four independent converter stations, each with a rated power of 103 MW. The built-in overload capability ensures constant power supply, even if one of the four converter stations is not in service.

In rolling stock, ABB is providing the traction transformers for Siemens Mobility's new flagship high-speed train, Velaro D. National rail operator Deutsche Bahn has ordered 15 eight-unit Velaro D trainsets for operation on international routes across four countries (France, Germany, Belgium and Switzerland) using four different power supplies. ABB has incorporated a number of design innovations to reduce the weight of the transformer and extend the maintenance intervals. The combined effects of these features make a significant contribution to the Velaro D achieving an operating speed of up to 320 km/h, while carrying 20 percent more passengers than its predecessor and consuming only 0.33 liters of gasoline equivalent per person per 100 km.

Service and refurbishment is a key component in ABB's high-speed offering. Deutsche Bahn's first fleet of high-speed intercity express trains, ICE 1, was built in the early 1990s. In 2005 it was decided that the trains were in need of extensive refurbishment. Deutsche Bahn selected ABB to replace the old thyristor-based traction converters with modern IGBT converters, while leaving all other components of the traction chain and all interfaces unchanged - the first time this had ever been performed on high-speed trains. The converter, developed within just 13 months, cuts energy consumption by at least 15 percent and significantly reduces operating costs, resulting in a high return on this modernization investment. The old power modules weighed 300 kg and were almost 1.5 m in length. ABB's new IGBT modules weigh less than 35 kg, have much smaller dimensions and can be handled by one person without lifting tools, thus simplifying service.

Switzerland

Switzerland is currently expanding its high-speed rail network to link up with those of neighboring Germany, Italy and France. The focal point of this large federal project is the construction of the Lötschberg and Gotthard base tunnels, which run several hundred meters below existing tunnels.

The 34.6 km Lötschberg base tunnel opened in December 2007. The tunnel supports the western transit link between Basel on the German border and Milan in northern Italy. ABB supplied the 50 Hz power distribution system for the entire tunnel infrastructure - lighting, signaling, communications, ventilation and air conditioning – as well as the 16.7 Hz traction power supply system that is designed to power up to six locomotives and freight trains of up to 1.5 km in length simultaneously. The solution includes a SCADA system and 314 cast coil dry-type transformers from 100 to 2,500 kVA.

REF 542*plus* is providing fault protection in the Gotthard tunnel

For the 57 km Gotthard base tunnel, which is scheduled to open in 2017 and will be the longest rail tunnel in the world, ABB is supplying a power distribution solution that will provide exceptional levels of reliability, availability and safety in the demanding operating conditions of the tunnel system. The tunnel system will consist of two tunnel tubes, one for each direction, linked every 325 meters by 40 m crossways that serve as escape routes. The ABB power equipment is located in these crossways. It has to withstand large variations in pressure caused by trains speeding past at 250 km/h, and unusually harsh operating conditions – salt deposits, brake dust, soot, and abraded material. ABB is also supplying 875 units of ZX0-type gas-insulated switchgear and 500 units of REF 542*plus* protection and control devices.

Italy

ABB was recently awarded an order to provide traction transformers for the V300ZEFIRO very high-speed train that Bombardier has developed in partnership with AnsaldoBreda. Known in Italy as the

ETR 1000, the V300ZEFIRO has a capacity of 600 passengers and is capable of commercial speeds of up to 360 km/h.

Bombardier's V300ZEFIRO trains, also known under the name of ETR 1000 in Italy, are fitted with ABB traction transformers. Source: Bombardier pictures press

Each trainset will be equipped with two underframe-mounted ABB traction transformers with integrated cooling systems. Ten of the traction transformers will be able to operate under four different electrical systems, enabling the trains to run cross-border services. ABB's traction transformers were chosen for their slim, compact and lightweight design, factors of paramount importance for very high-speed trains. The order follows the successful operation of 110 traction transformers and 280 traction motors on the ETR 500, which ABB delivered to Bombardier Transportation in 2004 and 2005. The traction transformers enable the ETR 500 to operate in two different power supply systems (25 kV/50 Hz and 3 kV DC) and at speeds of up to 300 km/h.

ABB is also supplying the traction transformers for the 25 very high-speed AGV trainsets that Alstom is supplying to the Italian private rail operator, Nuovo Trasporto Viaggiatori (NTV). The trains will begin operating on three routes in Italy later this year (2011). The AGV is designed to enable rail operators to fully customize their trains. This in turn required ABB to design a modular traction transformer platform that is capable of being customized to meet all operator requirements. This, while maintaining the usual ABB transformer attributes of compact footprint, low weight and performance excellence.

France

The Alstom AGV trainsets that NTV is scheduled to start running in Italy in 2011 are the first commercial deployment of Alstom's new generation of very high-speed trains. In 2007 the AGV set a new rail speed record of 575 km/h on a test run in France. The record run was designed to test the performance and reliability of infrastructure and material under extreme conditions. ABB was a principal partner of Alstom in the development of AGV technology, providing the traction transformer that is now such a key component of the AGV traction chain. The AGV is 35 tons lighter and consumes 15 percent less power than the preceding TGV generation. By designing a compact and lightweight transformer that can be mounted under the floor and operate at any voltage in any part of Europe, ABB played a crucial role in the development of this record-breaking train.

Spain

Spain has the largest high-speed rail network in Europe, and the third largest in the world after China and Japan. By 2020, some 90 percent of Spain's 46 million inhabitants are expected to live within 50 km of a station served by AVE (Alta Velocidad Española) trains operating at speeds of up to 350 km/h. ABB is extensively involved in supplying solutions for both the high-speed lines and the rolling stock.

ABB supplied the traction transformers for the AVE S-102, S-112 and S-130 trains that Talgo and Bombardier have jointly developed for the AVE network. Known outside of Spain as the Talgo 350, the trains are designed to operate at speeds of up to 350 km/h. Forty-six trainsets, each equipped with two ABB traction transformers, have been delivered to date. A total of 45 Talgo 250 trainsets , each powered by two traction transformers, are currently operating on AVE services in Spain at speeds of up to 250 km/h and at two different voltages and on variable gauges.

ADIF, which owns and operates the Spanish rail network, signed a frame agreement with ABB in 1990 for the supply of substation transformers for the entire high-speed rail network. To date ABB has delivered around 140 distribution and traction power supply transformers for the ADIF-operated network. Most recently, ABB was selected to supply all the transformers for the Barcelona-Figueras section of the high-speed line that will link Madrid with the French border. The contract was awarded by a Siemens/Inabensa consortium, and is for six 60 MVA power transformers that will be installed in substations along the new section.

United Kingdom

London is connected to Paris and Brussels via the High Speed 1 rail link. Formerly known as the Channel Tunnel Rail Link, the 108-kilometer high-speed line runs from London St. Pancras to the British side of the Channel Tunnel. The line was completed in 2007, enabling trains to travel at speeds of up to 300 km/h before entering or leaving the tunnel on their way to or from Paris or Brussels.

EDF Energy, the transmission system operator for this part of the U.K. power grid, selected ABB to provide a traction supply package that would enable the trains to run reliably at high speed without impacting power

quality in the surrounding grid. The solution consists of three 400/33/25 kV feeder substations and four 2x25 kV autotransformer stations that feed and distribute power along the entire High Speed 1 link. Two static var compensators (SVCs) are installed at each of the feeder substations to maintain the power factor at unity, provide voltage support in case of a feeder substation outage, and mitigate harmonics. A seventh SVC provides dynamic load balancing to prevent the high-speed rail network from impacting the nearby Cross Channel HVDC power link (high-voltage direct current) between England and France.

Dynamic load balancer at Sellindge near the British coast and Channel Tunnel

Other major European routes

ABB supplied the traction transformers for the 12 AnsaldoBreda trainsets that operate on the Amsterdam-Brussels route at speeds of up to 300 km/h. The line opened in 2009 and connects Amsterdam to other major European cities like Cologne, Paris and London. Each trainset is powered by four ABB traction transformers that enable the trains to operate in three different power systems: 25 kV AC, 3 kV DC and 1.5 kV DC.

ABB traction transformers are also powering the new Alstom Pendolino high-speed trains that link Helsinki, the capital of Finland, with St Petersburg in Russia. Each of the four trainsets is equipped with two traction transformers that allow the train to switch smoothly between 25 kV and 3 kV DC power systems. They are specially designed to operate in the harsh winter climate of this part of Europe at temperatures of minus 40 degrees Celsius.

China

China is in the midst of a huge rail investment program, upgrading conventional railway lines and constructing tens of thousands of kilometers of high-speed passenger lines.

Within the next 10 years, a cross-country network of four north-south and four east-west passenger lines will be completed, as well as a web of intercity passenger connections between developed and densely populated areas. The total operating rail network will exceed 120,000 km, more than 60 percent of which will be electrified. And the total length of high-speed passenger lines will surpass 18,000 km, almost half of which will be 350 km/h lines.

By 2020, when the medium- and long-term targets of the program are achieved, China will have created the world's fastest and most technologically advanced high-speed rail system.

ABB is playing a leading role in this unprecedented rail development program by providing critical power technologies for both rolling stock and the electrified rail systems on which they run.

ABB traction transformers first entered the Chinese railway market in 2004 when they were selected for Bombardier's Regina trains, known in China as CRH1A and CRH1B 1. In 2009, Bombardier Sifang Power won a further contract to supply the Chinese Ministry of Railways with 80 Zefiro 380 very high-speed trains. More than 1,000 Bombardier-design rail cars are being built for China's new high-speed railways, and ABB is supplying the traction transformers for all of them.

ABB traction transformers can also be found on some of Siemens Mobility's Velaro high-speed trains. Known in China as the CRH3-380, these trains are capable of service speeds of up to 380 km/h. In 2009, ABB was contracted by Datong Electric Locomotive Co Ltd to deliver traction transformers for the CRH2 (a modified E2-1000 series Shinkansen design from Japan) and to manufacture traction transformers for the CRH5 electric multiple unit (EMU) trains manufactured by Alstom and Changchun Railway Vehicles. Also in 2009, ABB was selected to upgrade the traction transformer design for the Kawasaki-derived CRH2-380, an EMU train capable of speeds of up to 380 km/h.

Traction transformers are not the only power products supplied by ABB for China's high-speed networks. For the Wuhan-Guangzhou high-speed rail project, ABB supplied a series of products, including its 27.5 kV ZX1.5-R and 10 kV ZX0 gas-insulated switchgear, as well as the SAFE-series SF_6 insulated switchgear that is used in the railway signal system power supply. The ZX1.5-R switchgear was specially designed at ABB China's medium voltage technical center to address the highly specific power supply requirements of China's high-speed railways. The switchgear uses up to 70 percent less space than conventional switchgear. Insulation is provided by SF_6, which is well known for its remarkable physical characteristics, especially its excellent insulating capacity. With fewer maintenance requirements, customers are able to

lower their total investment and operating costs.

ABB is also contributing significantly to China's future development of high- and very high-speed rail by setting up the ABB Electrified Railway Training Center in cooperation with Beijing Jiaotong University. ABB has donated advanced railway traction equipment to the center, which will provide teaching, research and training facilities for Ministry of Railways' personnel and university teachers and students.

For more information:

ABB Railway portal: www.abb.com/railway

ABB Review special edition on railways and transportation: www.abb.com/review