# On the fast track

## ABB is contributing to high-speed trains

PASCAL LEIVA, MELANIE NYFELER – The importance of mobility is growing. It is becoming more and more common for people to travel distances of hundreds of kilometers between major cities for work or leisure. This is increasing pressure on motorways, railways and short-haul flights. Concerns over carbon emissions and congestion of road and air space are causing many countries to reassess their transportation policies. Studies show that traveling by rail requires a quarter to one-third the $CO_2$ of the same trip by plane or car[1]. High-speed trains are particularly effective at taking pressure off short-haul flights and bringing cities closer together.

13,469 km of high-speed lines are under construction and 17,579 km are planned. The world's high-speed network could reach 41,787 km by 2020.

The Eurostar service through the Channel Tunnel cut journey times between Paris and London to 2 hours 15 minutes and now represents 70 percent of the travel market between the two capitals [1]. The Madrid-to-Barcelona high-speed link reduced intercity travel time to 2.5 hours and grabbed 50 percent of the market. High-speed trains have scored similar successes on the Paris-Lyon, Paris-Brussels and Hamburg-Berlin lines (among others). In the wake of these successes, governments across the world are seeking to invest in high-speed railways.

## Speed ≥ 250 km/h

High-speed trains can offer numerous advantages: These include reduced journey times, increased frequency, comfort, safety, reliability and less environmental impact. The International Union of Railways (UIC) defines high speed as operations of at least 250 km/h (the maximum speed for conventional lines is 200 to 220 km/h). Typical attributes of high-speed trains are:

- Use of train sets rather than conventional locomotive and cars formations. These offer better power-to-weight ratios, aerodynamic conditions, reliability, safety, etc.
- Use of dedicated high-speed lines on at least part of the journey. Such lines are built to sustain high speeds (through their choice of transverse sections, track quality, catenary, power supply, special environmental conditions, etc.) However, one strength of high-speed trains is that they can also operate on conventional lines with certain restrictions [2], so reducing the necessary investment or permitting a phased introduction.
- Use of advanced signaling systems, including in-cab signaling.

## Development of high speed trains

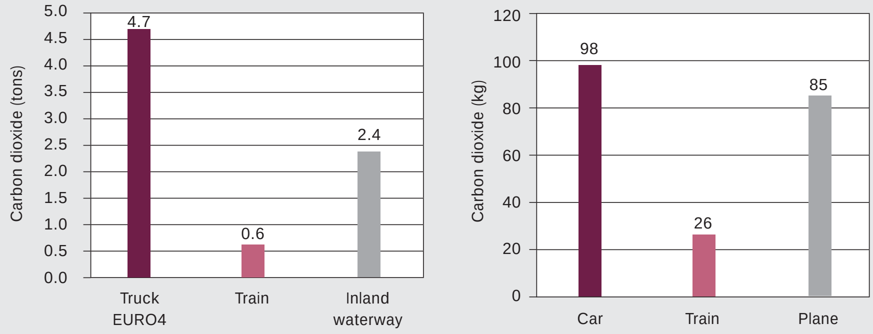
As early as 1903, a speed of 210 km/h was attained using an experimental three-phase electrification in Germany, demonstrating the aptitude of electric traction for high speeds. In 1955, a series of tests in France culminated in a record of 331 km/h. Notably, the trains and catenary used were closely based on equipment that was used in everyday service. This demonstrated the safety margins of the technology and indicated the feasibility of the commercial operation of high-speed trains.

Day-to-day speeds, however, remained much lower, with the fastest trains operating at top speeds of around 160 km/h → 1. The first commercial train that can be considered high speed in the modern sense is the Japanese Shinkansen. It was inaugurated in 1964 on the 515 km line between Tokyo and Osaka, and initially operated at a top speed of 200 km/h (increased to 210 km/h the following year). This route is still the world's busiest high-speed corridor, carrying more than 360,000 passengers every weekday. Today, Shinkansen trains oper-

Footnote

1 The environmental impact of a journey in Europe can be calculated on www.ecopassenger.org.

Environmental performance of rail

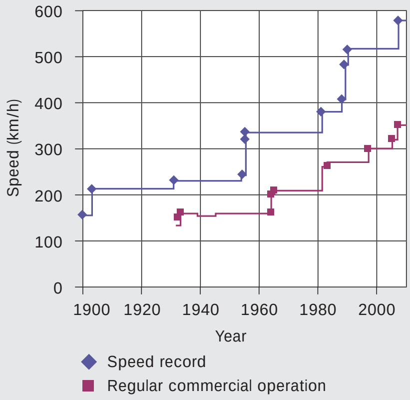



$CO_2$ emissions by transport type
(100 tons cargo, Basel – Rotterdam, 700 km)

Carbon dioxide ($CO_2$)
(2 people, Berlin – Frankfurt, 545 km)

Source: www.ecotransit.org, 2008

1 The development of high-speed rail




ate at a top speed of 300 km/h, with higher speeds being planned.

France inaugurated its first TGV (Train à Grande Vitesse) train in 1981, connecting Paris and Lyon (417 km). The initial maximum speed of 260 km/h has incrementally been raised to 320 km/h. At 1,900 km, France today has Europe's largest high-speed rail network. There are plans to increase this to 4,000 kilometers by 2020. SNCF, RFF [2] and Alstom Transport hold the world speed record of 575 km/h, achieved on a test run in April 2007.

## ABB has strategic alliance contracts with many rolling stock manufacturers including Alstom, Bombardier, CAF, Siemens, Skoda and Stadler.

Spain, however, plans to surpass France's high-speed network in terms of length. It is envisioned that by 2020, 90 percent of all Spaniards will live within 50 km of a station served by AVE (Alta Velocidad Española) trains. The top speed of these trains will be 350 km/h.

Today, Belgium, France, Germany, Italy, Spain, the United Kingdom, Taiwan, Japan, Korea and the United States have high-speed lines in operation. China, Iran, the Netherlands and Turkey have systems under construction and Argentina, Brazil, India, Morocco, Poland, Portugal, Russia and Saudi Arabia have systems under development. Globally, there were 10,739 km of lines for 250 km/h or greater in 2009, with almost 1,750 train sets in service [3]. A further 13,469 km of lines are under construction and 17,579 km are planned. The world's high-speed network could reach 41,787 km by 2020 [4].

ABB has been playing a major role as a supplier to the railway industry for several decades. Drawing on its expertise in the power and automation sectors, the company is contributing reliable and cost-efficient solutions for both infrastructure and rolling stock.

## Infrastructure

ABB designs, engineers, constructs and commissions complete traction power supply products, systems and solutions. The company supplies a comprehensive range of traction substations containing all the necessary switchgear and fault analysis equipment. ABB's portfolio includes:

- Products for traction power supply applications
- Traction substations for AC and DC applications
- Static frequency converter stations.
- Power quality systems
- Network management systems
- System analysis and dynamic traction power supply simulations

### Static frequency converters

Much of the electric energy used by railways is drawn from national grids. However, for historical reasons, the frequencies used for railway electrification often differ from these grids. The state-of-the-art solution is converters using power electronics → 3.

### FACTS for power quality

Modern traction systems present demanding challenges to supply grids. Usually, the single-phase railway supply is connected between two of the three phases of the national grid. It can hence cause a substantial imbalance in a network not originally built for this kind of operation.

ABB offers different solutions to maintain power quality in grids. Dynamic shunt compensation devices of the SVC or STATCOM types use power semiconductors to control reactive power. Thanks to their cycle-by-cycle controllability, they can counteract even the most rapid voltage transients and protect the grid from serious voltage variations. Additionally, they can control the grid's voltage profile and raise its stability limit, enhancing grid capacity while making it more robust, flexible and predictable.

A total of four SVCs have been supplied for the Channel Tunnel Rail Link (the high-speed line linking the Channel Tunnel to London). Each of the three feeding points is supported by an SVC on the traction side of the transformer. The

Footnote

2 SNCF (Société Nationale des Chemins de Fer Français) is the French national railway company. RFF (Réseau Ferré de France) is the French railway infrastructure agency.

## 2 Transformers for Spanish high-speed lines

ABB won the contract to supply all transformers for the Barcelona-Figueras section of the AVE line that will connect Madrid via Zaragoza and Barcelona to the French border. These transformers will be located in the substations along this section at Baro de Viver, Riudarenes and Santa Llogaia.

The contract was awarded by the SILFRA-SUD consortium, made up of Siemens and Inabensa, and consisted of four transformers of 60 MVA, 405 / 27.5 kV produced in ABB's Cordoba factory and two transformers of 60 MVA, 220 / 27.5 kV made in ABB's Bilbao factory, Spain.

Since 1990, ABB has supplied a total of 85 transformers for high-speed lines all over Spain, and it is also the selected supplier through a frame agreement signed with ADIF (the Spanish rail infrastructure administrator), which covers the supply of traction transformers until 2014 and includes 52 additional units.

## 3 Static frequency converter projects

ABB is currently realizing the world's largest and most powerful static converter system in conjunction with E.ON Kraftwerke GmbH of Germany. This converter system is rated at 413 MW and connects the 50 Hz national grid to the 16.7 Hz railway grid. The completion of the order is scheduled for 2011. Other static frequency converters supplied to German Railways include the eight 15 MW units at Limburg supplying the high speed line between Cologne (Köln) and Frankfurt am Main. Converters have also been supplied to the Austrian and Swiss railway operators.

For more information on these projects, please see "Static converters, dynamic performance" on page 42 of this issue of *ABB Review*.

fourth SVC is used for load balancing. This technology is discussed more fully in "Knowing the FACTS" on page 35 of this issue of *ABB Review*.

### Transformers

A high-speed train can draw considerable power, especially while accelerating. Transformers convert the grid voltage to the correct line voltage for the railway ➔ 2.

## Rolling stock

Manufacturers of high-speed trains are continuously refining their designs to meet rising demands in terms of performance, efficiency and reliability, and are placing similarly high demands on their suppliers. In recent years, ABB has extended its expertise for traction transformers and is now the world leader in this field. The company has strategic alliance contracts with the rolling stock manufacturers including Alstom, Ansaldo Breda, Bombardier, CAF, Siemens, Skoda and Stadler. Various types of traction transformers have been designed and delivered to practically all railway integrators and are in use all over the world.

### Traction transformers

A traction transformer is a key component of a train's onboard traction chain. Special criteria it must fulfill include:

– It is a single transfer point for energy between catenary and motors, and must therefore meet high reliability levels.
– It must be compact in terms of size and weight.
– Many transformers must deal with multiple voltages and frequencies due to the different electrification systems used across Europe (and sometimes within one country).

An ABB traction transformer was used on the record-breaking AGV train that attained 575km/h in April 2007, ABB is supplying traction transformers for the high-speed trains of Alstom (AGV) ➔ 4, Siemens (Velaro) ➔ 5 and Bombardier (ZEFIRO) ➔ 6.

The evolution of market requirements has led to the following situation: While "classical" European high-speed trains such as the ICE-1 and the TGV are powered by dedicated power units at the ends of the train, the new generation of high-speed trains such as the Velaro and the AGV use traction distributed along their entire lengths. This permits a better use of adhesion due to the lower power required per axle. Furthermore, by placing the complete traction chain under floor (including transformers, converters, motors and control equipment), practically the full length of the train is available for passengers (a gain of up to 20 percent). The transformers ABB is supplying for both AGV and Velaro are compatible with Europe's main railway voltages and frequencies.

> An ABB traction transformer was used on the record-breaking AGV train that attained 575 km/h in April 2007.

### Traction converters

ABB has supplied traction converters for the retrofit project of DB's (German Railways) ICE-1. This is discussed in the inset on page 76.

### Motors

Together with Bombardier, Ansaldo Breda, Alstom, and Firema, ABB is part of the Trevi Consortium supplying the ETR 500 to Trenitalia (Italian railways). Trenitalia chose to electrify its new high-speed lines at 25 kV AC rather than the 3 kV DC used on the classic network. Therefore, between 2006 and 2008 the 3 kV ETR 500 fleet was upgraded for dual voltage capability. In February 2006 the trains commenced regular service at a commercial top speed of 300 km/h on the new high-speed lines connecting Milan to Turin, Florence, Rome and Na-

4 AGV: Transformation at speed

SNCF, RFF and Alstom Transport broke the world speed record for classical wheel-on-rail technology in a test run on April 3, 2007, during which the train reached 575 km/h. The new generation of AGV-trains (Automotrice à Grande Vitesse) of Alstom Transport will attain commercial speeds of 360 km/h. An increased use of composites and aluminum allowed Alstom to make the AGV lighter: An entire train weighs 395 t (compared with 430 for a TGV) and uses 15 percent less power.

The first new AGV train will enter service in late 2011 in Italy and be operated by a new private company: NTV (Nuovo Transporto Viaggiatori). NTV has ordered 25 trains.

Picture: Alstom Transport

5 Velaro: The new generation

In June 2009, Siemens Mobility selected to use ABB transformers for their flagship Velaro high-speed train for DB (Germany Railways).

Two traction transformers will be fitted to every eight-car train. In order to reduce weight, the secondary windings of these transformers also serve as line inductances for the power converters when the train is operating under a DC power supply.

See also “High-speed transformation: Transformers for the Velaro high-speed train” on pages 64–67 of *ABB Review* 4/2009.

Picture: Siemens press picture

6 Orders for China, Spain and Italy

In September 2009, Bombardier Transportation announced that its Chinese joint venture, Bombardier Sifang (Qingdao) Transportation Ltd., was to supply 80 ZEFIRO 380 km/h high-speed trains for the country’s rapidly growing high-speed rail network *. ABB will supply the traction transformers.

ABB Sécheron also supplied the traction transformers for the AVE high-speed trains that Bombardier is jointly producing with Talgo (Talgo/Bombardier AVE102 and Talgo/Bombardier AVE130) for RENFE (Spanish Railways) and for the ETR 500 for TrenItalia (Italian Railways).

Picture: Bombardier press picture

Footnote

* See also “China’s rail revolution” on the following pages.

ples. ABB delivered more than 280 traction motors for the ETR 500. For more information on ABB’s traction motors, see “Standardizing the traction motor” on page 66 of this edition of *ABB Review*.

## Fast growing market

Looking at present orders and deliveries, 2,500 high-speed trains capable of running at over 200 km/h will be in operation worldwide by the end of 2010. China alone has 10,000 km of new high-speed lines under construction and an additional 3,000 km are planned [4]. The western European market is also still growing, and the replacement of first-generation high-speed trains will commence soon in France and Germany. Developments in the eastern European, South American and North African markets are also likely to lead to growth in the high-speed market. In the United States, President Barack Obama has vowed to spend $13 billion over five years to develop high-speed rail links between major cities. The outlook for high-speed rail is bright.

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