
Siemens press picture

# High-speed transformation

## Transformers for the Velaro high-speed train

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**Concerns over carbon emissions from transportation, combined with the increasing congestion of road and air space are causing many countries to rethink their transportation policies. New investments in transportation, such as commuter systems to serve major cities, or high-speed lines to connect cities over distances of several hundred kilometers, are contributing significantly to fuel savings and the reduction of $CO_2$ emissions.**

**High-speed rail is particularly effective at taking pressure off short-haul flights, reducing air congestion and bringing cities closer together. Japan and several European countries have been investing in high-speed railways for several decades and now have extensive high-speed networks. The rapid development of emerging economies, together with concerns ranging from rising fuel prices to global warming, have led more and more countries, on different continents, to look toward high-speed trains as an alternative transport solution. Manufacturers are meeting this growing interest by rolling out a new generation of ultra-fast trains – offering higher performance and more sophisticated technology than their predecessors.**

**One of these trains is Siemens' Velaro.**

ABB Sécheron traces its collaboration with Siemens Mobility to 2003, when ABB won a significant order to supply 140 +100 traction transformers for the double-decker trains of the Siemens' Desiro family for the suburban rail system of Zürich, Switzerland (S-Bahn Zürich) 1. A special challenge here was that the transformer had to be extremely light and compact as the design objective of the train was to maximize the space available for passengers.

In 2004, ABB was awarded an order to supply 172 EMU (electrical multiple units) transformers for suburban services in the Mumbai area (India). In this project, ABB's ability to provide local content proved an advantage in obtaining the contract. A second major Mumbai order followed in 2006 Factbox 1.

Building on this success, ABB secured a further traction transformer contract with Siemens in 2008, this time for trains destined for the Scottish railway franchise, Scotrail.

In June 2009, ABB won a prestigious order with Siemens Mobility: to supply transformers for Siemens' flagship Velaro high-speed trains.

The ICE-3 and Velaro differ from the first generation of European high-speed trains in that they are not pulled by dedicated locomotives or power units, but use a distributed-traction concept.

### The Velaro high-speed train

Velaro traces its origins to the ICE-3 train, which was supplied to German Railways (DB) from 2000, and operates at speeds of up to 320km/h in commercial service 2.

The Velaro is a development of the ICE-3. In contrast to its predecessor, for which Alstom LHB, Bombardier/DWA, and Siemens were jointly responsible, the Velaro is entirely the responsibility of Siemens Mobility. Velaro trains have been sold to Spain (2001: 26 eight-car trains for Madrid – Barcelona), China (2005: 60 eight-car trains for Beijing – Tianjin and 2009: 20 eight-car trains and 120 16-car trains for Beijing – Shanghai) and Russia (2006 : eight 10-car trains for Moscow – St. Petersburg). With a power of 8,800 kW, (10 percent more than the ICE-3) the Spanish train can reach a top speed of 350 km/h.

The ICE-3 and Velaro differ from the first generation of European high-speed trains in that they are not pulled by dedicated locomotives or power units, but use a distributed-traction concept. This means that all traction equipment such as traction motors, transformers, cabling and auxiliary equipment is distributed along the subfloor space of the vehicles. As a result, the full length of the train is available for passenger accommodation. This approach permitted the capacity of the

**Factbox 1** Mumbai suburban railway

The Mumbai suburban railway has the world's highest passenger density: It is used by 6.3 million commuters every day. The system extends over 319 route km (790 track km) and is divided between two of India's zonal railways: Western Railway (WR) and Central Railway (CR). It uses a total of 191 train rakes (train sets) to operate, 2226 daily train services.

To alleviate overcrowding and provide additional capacity, a massive investment program has been launched. This includes:

- Boosting capacity by adding 181 km of additional tracks
- Extending station platforms to permit longer trains
- Improving signaling systems to permit trains to run at shorter intervals
- Procuring new trains

The works will permit the total number of trains operated every day to be increased by 25 percent. Overcrowding will be alleviated by reducing the commuter load of a 9-car train from 5,000 to 3,600 passengers.

The total cost of these measures is estimated at $943 million*) of which 57 percent is provided by a World Bank loan.

The first phase included the procurement of 101 new trains of 9 cars each, with 97 more following in the second phase. As the works also include a phased conversion of the railway's electrification system from 1,500 V DC to 25 kV 50 Hz, the new trains are dual voltage, permitting them to work on both systems during the transition period.

The trains are being built by Siemens in cooperation with the Indian company, Integral Coach Factory (ICF). ABB is sub-contracted to supply the traction transformers.

Source: Integral Coach Factory (ICF)

Further features of the new trains include:

- Energy savings of 30 percent due to regenerate braking
- Use of three-phase traction motors permits 20 percent higher power
- Top speeds of 100 km/h rather than 80 as on previous train types
- Higher acceleration 0.54m/s² as compared to 0.38 for previous trains.
- Decelartion similarly improved to 0.76 m/s² from 0.6.
- Journey time on a typical Churchgate – Borivali or CSTM – Thane trip reduced by four to five minutes.
- Passenger comfort improved through a broad range of measures including better riding quality, improved ventilation, passenger information displays and better lighting.

For more information, see www.mrvc.indianrail.gov.in .

*) 45,260 million Indian Rupees

1 A Desiro Double Deck or train of Swiss Federal Railways (SBB) used on the Zürich suburban system (S-Bahn Zürich). These trains have ABB transformers. [Siemens Press Picture]

2 An ICE-3 high-speed train of German Ralways (DB). These trains have a top speed of 320km/h.

train to be increased by some 20 percent while at the same time augmenting levels of passenger comfort.

The next Velaro order was placed by German Railways (DB) in December 2008 3. These 15 trains differ from the previous Velaro orders in that the train will be used on international services and must be equipped to work in four countries (France, Germany, Belgium and Switzerland). They must operate under four different power supplies and be compatible with the different safety and signaling systems of the respective countries.

In June 2009, Siemens Mobility entrusted the supply of the traction transformers to ABB. Ralf Mayer of Siemens Mobility said "ABB met the challenging requirements, eg, size and weight, of these special transformers in a very convincing manner – so we chose ABB as a reliable partner for the Velaro D project."

### The Velaro challenge

The Velaro's transformer posed several engineering challenges.

If a traction unit fails, the train must be able to continue its journey with 75 percent of its maximum traction and brake power in complete safety. This includes the train's ability to start and stop on steep gradients (the train is expected to cope with gradients of up to 4 percent, double that of conventional trains).

All this is achieved at great levels of energy efficiency. With an equivalent gasoline consumption of 0.33 liters per person per 100 km, Siemens claims Velaro to be the "world's most ecological train."

Two traction transformers will be fitted to every eight-car train. In order to save 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. Thanks to this economic weight-saving principle, the mass of the entire transformer assembly (comprising the 5,220 kVA traction transformer and its cooling system) could be reduced to 7,700 kg.

## The traction transformer and its cooling system jointly form a plug-and-play assembly.

This principle of combined use of windings was first installed on the Italian locomotive type, E412, in 1996. It has since been adopted by other vehicle types including the ETR 500[1], AGV[2] (NTV[3] high-speed trains) and the Traxx MS[4] locomotive.

The transformer's enclosure is manufactured out of weight-saving aluminum. Further weight is saved by integrating the expansion reservoirs (for the coolant fluid) with this unit. The cooling system uses 60 Hz motors rather than the more common 50 Hz ones permitting their mass to be reduced without sacrificing cooling performance.

Capacitor-based filters have been added to reduce resulting harmonics. Railway applications are extremely sensitive to harmonics as these can cause interference with signaling systems. Hence requirements are very stringent, demanding great diligence in addressing such issues.

The traction transformer and its cooling system jointly form a plug-and-play assembly, useful for installation and for maintenance. This was an unusual concept for Siemens, as the company normally sources the transformer cooling system separately from the transformer. The unit does not require de-gassing or oil refilling, and so can operate for prolonged periods with minimal intervention.

Further challenges were posed by the very demanding timelines to which ABB had to work, as Siemens required the delivery of the first transformer in December 2009.

**Footnotes**

1) ETR 500 is a high-speed train operated by Italian Railways (Trenitalia) and manufactured by a consortium of suppliers.

2) AGV (automotrice à grande vitesse) is a high-speed developed by Alstom as a successor to the TGV. Similarly to the Velaro, it uses distributed traction.

3) See Factbox 2.

4) Traxx is a family of universal locomotives manufactured by Bombardier Tranportation.

3 Impression of the Velaro-D train that will be supplied to DB [Siemens press picture]

4 An ABB traction transformer for the Velaro D train

**A future at high speed**

ABB Sécheron has managed to build an excellent working partnership with Siemens Mobility. This was based both on ABB's ability to draw on its expertise in traction-transformer design and apply this to the demands of high performance under restricted space and weight limitations Factbox 2, but also its high responsiveness and willingness to collaborate. ABB's support staff made themselves available at all times, including weekends, to attend to queries at meetings, by phone, e-mail or on-site to share their expertise.

Siemens' ability to rely on ABB is of the greatest importance. Being responsible for the project, Siemens must bear the liability and penalties for late delivery or malfunctions of the finished train – yet with acceptance procedures being required in four countries, the timeline is extremely demanding. Siemens must thus be able to count on reliable partners who will do everything in their power to avoid inducing delays of their own. ABB is in continuous contact with Siemens to discuss progress and review technical issues. At the same time, ABB is working together with the end customer (DB) on various quality-related issues defined by the customer such as enclosure welds.

With projects for high-speed trains being considered in many countries and continents, fuelled by environmental concerns, airspace congestion or driven by the rapid economic growth of many developing countries, the global market for high-speed rail is certain to see some exciting development in years to come. ABB's motto for rail transport of the future is "Let the brain fly but your body takes the train."

Railway applications are extremely sensitive to harmonics as these can cause interference with signaling systems.

The Velaro project is not only a good starting point for further high-speed orders, but also demonstrates ABB's competence in the design and supply of traction transformers for all types of applications.

Factbox 2 ABB and high speed

ABB draws on considerable experience in designing and manufacturing transformers for high-speed trains. The highlights of this include:

- The TGV/AGV train that set the world speed record of 574 km/h on April 3rd 2007 (see inset photograph) used an ABB transformer. The train had conventional power cars at the extremities, and additionally used two AGV power bogies under the passenger cars.
- NTV (Nuovo Trasporto Viaggiatori, Italy's first private operator) will use AGV trains equipped with ABB transformers.
- Siemens Velaro for DB uses ABB transformers.

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