Performance on track

Electric power products on trains – designed by ABB to make journeys more comfortable

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Today's economy is dependent on the movement of goods and people. Without an efficient and affordable transportation system, people would have less choice in terms of what goods they could buy or where they could live and work. At the same time, this transportation is expected to have the lowest possible environmental impact. Electrical trains are well positioned to fulfill these demands. They offer large capacity, low energy consumption, minimal use of space, and quasi absence of pollution. No wonder that new railway lines are being built everywhere in the world, addressing on the one hand the need for high-speed city-to-city connections over some hundreds of kilometers as an alternative to air travel; and on the other hand urban transportation in growing metropolises that are more and more congested by cars.

In order to gain further market share against cars and airplanes, a reliable and safe railway service is primordial. Further reduction of travel time, increased comfort, and safety are crucial success factors in further attracting patronage. This article presents some of ABB's contributions to these goals.

When people ride a train, a metro or a tramway, only few ever think of how the electric components on that vehicle determine their travel comfort. The first aspects that may come to mind in this respect are heating, ventilation and air conditioning (HVAC), lighting, power supply for laptops and other onboard entertainment devices.

"Comfort devices" on board

The power demand on trains and urban-transit vehicles has risen constantly over the years. HVAC, automatic doors, passenger information systems, video surveillance systems or closed-system toilets have become a standard for new vehicles in most transport systems. These so-called auxiliary systems today typically require a power supply capacity of about 400 to 800 W per seat.

On some special types of coaches or trains, this power demand is even higher: for example, kitchen equipment in a dining car or showers in a sleeping coach.

ABB BORDLINE® M auxiliary converters

What is ABB's contribution to these features that add to passenger comfort in so many ways? Auxiliary power converters adapt the main electricity supply to the voltage and current needed for different groups of onboard applications. They belong to that class of utilities that people wish

to have but don't wish to perceive. Such systems should not be heard, nor should they occupy space that could otherwise serve the passenger. Considerable progress has been made in increasing the power density of these devices, in developing a more compact design and in reducing the noise emissions of the necessary cooling and of the high-power switching devices. ABB BORDLINE® M auxiliary converters can be flexibly mounted under-floor, on the roof or even within the cabinet of other on-board power devices 1.

Auxiliary power on a transport vehicle should be available without interruption. ABB designs redundant supply and battery management systems that assure the continuity of the auxiliary power supply irrespective of short outages during train operations. For trains crossing borders between different line voltages, ABB provides multi-system auxiliary converters that automatically adapt to the voltage system. These are discussed in more detail later in this article.

Some of ABB's auxiliary converters add to the traveler's comfort in yet another way: They drive a tilting system for trains, which are able to run on winding tracks faster than conventional trains.

1 BORDLINE M30, a compact auxiliary converter for mounting on the roof of a light rail vehicle. It supplies power for numerous auxiliary applications.

Shorter travel times

With help of auxiliary converters, the traveler can enjoy those luxury amenities on board that he or she is used to in everyday life (but cannot use in a car; for example, a laptop, bistro, a washroom or a bed). However, one of the most important factors that determine the value of a journey or a short commuter trip is travel time – the shorter the better. High maximum speed is expected in long-distance travel while in urban transit one needs fast and smooth acceleration and braking. Clearly, the propulsion system is central in shortening travel times. ABB supplies the main electric components of an electric or diesel-electric propulsion system: motors, power electronics, high-power switches Factbox 1, transformers, and generators. A closer look at ABB's transformers and compact converters shows how these components not only increase travel speed, but are also designed to cater to other aspects of passenger comfort: more space, less noise, more reliable schedules, travel without changing trains, safety.

ABB traction transformers

The transformer is a single transfer point for energy between catenary and motors, imposing the highest reliability demands. Any transformer breakdown would stop the train immediately (or run it at decreased speed if there is a second transformer in an independent propulsion chain). The transformer is thus highly relevant in terms of reliability and performance.

Convenient access and more space

Traction transformers need to be of the smallest possible size since space is at a premium, especially in vehicles using the concept of distributed propulsion (electrical multiple unit, EMU)

2 A portfolio of examples of trains equipped with ABB traction transformers

which has become dominant today. ABB has developed different solutions to this end, either placing the transformer under-floor (typical for high-speed train applications, such as the new TGV generation in France, ETR 500 in Italy, or TALGO 350 in Spain) or mounting it on the roof of the vehicle (such as in Bombardier's NINA, Alstom's X60, or Stadler's FLIRT trains) 2. In both cases, the transformers need to be very flat, enabling a low floor design of the vehicle. Low floor translates into easier access, a big improvement especially for disabled passengers, or passengers traveling with bulky luggage, baby carriages or bicycles. Faster access in turn enables lower dwelling times at stations, permitting faster services and better utilization of line capacity.

The transformer should be of lowest possible weight, as axle weight limits may typically not exceed 22.5 t or even more restrictively, 17 t for certain high-speed or narrow-gauge trains. Lower weight additionally means that less energy is needed to accelerate and slow down the train, hence assuring a better use of electrical power. The under-floor mounting of the heavy traction transformer lowers the center of gravity and thereby increases the comfort, especially when traveling at high speed.

On a regional train, a cabinet the size of a cupboard can hold the propulsion converter, auxiliary converter, battery charger, line filter and the main switch for the power head.

Safety – invisible comfort

Traction transformers and converters, along with other equipment on the train, have to fulfill strict safety standards Factbox 2. This is particulary true regarding fire and smoke. In the design of their oil-filled traction transformers (the oil is used for dielectric insulation and cooling), ABB takes great care to minimize the risk of fire in all imaginable situations. In the unlikely event of such an accident occurring nevertheless, the appropriate choice of materials ensures a minimization of risk to passengers' health.

With under-floor or roof-mounted transformers, passengers may sit very close to the transformer. Besides safety aspects, there are also limits on the resulting electromagnetic emission that have to be respected. This is taken into account in the design of the active part, the connections and the tank of the traction transformer. ABB's advanced knowledge contributes to the shielding of the magnetic field, which is also applied to the design of traction converters.

Reduction of noise

Another aspect of comfort is the minimization of noise emission. The primary source of acoustic noise generation in a transformer is the periodic mechanical deformation of the transformer core and the winding coils under the influence of fluctuating electromagnetic fields. During a transformer's operation, the vibrations from its core and windings are transmitted to the transformer tank and its surface and then radiated as noise into the exterior air.

Several different means of noise reduction have been studied and can be implemented in ABB traction transformers. These include fixing the transformer to the vehicle through dampers that isolate the train against vibrations, using grain-oriented core

Factbox 1 Medium-voltage vacuum circuit breaker AC Trac

Medium-voltage (MV) vacuum circuit breaker AC Trac is a further product in a train's traction chain that is essential for safety on board. The newly launched MV circuit breaker is installed on the roof of the vehicle and can be used both for 25 kV / 50 Hz and 15 kV / 16.7 Hz applications. Its main function is to protect transformer, converters and all other electrical components from dangerous over-currents such as short circuits, which are very often encountered in railways.

Factbox 2 Converter as an emergency brake for Zugspitzbahn

Mountain railways have strict requirements regarding safety, in particular for braking systems. In case of a power failure, mechanical braking systems must stop the train. But the mechanical brakes are not designed for use during the whole descent from the mountain.

ABB's Compact Converters in the rack-rail vehicles for Bayerische Zugspitzbahn resolve such an emergency situation with a special braking control function: Since line voltage is not available, the DC link is first charged using the vehicle battery. Then, the mechanical brakes are released, the converters turned on and finally, the motors start operating as generators to brake the vehicle. In order to stay in this operational mode, a minimum speed is necessary to support the DC link voltage of the converters, and hence mechanical braking must set in again to stop the train on arrival at the final destination. Passengers cannot perceive that this is an emergency situation because the train rolls down the mountain as usual.

Moving ahead

steel with reduced magnetostriction, and stacking the steel sheets differently (step-lap technique). Also, the external cooling system of the transformer could be a source of noise and therefore merits a high degree of attention in the design stage.

Besides technological leadership, ABB also enjoys a distinct market leadership position in traction transformers. Various types have been designed and delivered to practically all existing railway integrators and can be found everywhere in the world and in all different applications (locomotives, high speed, EMUs). An ABB traction transformer was installed on the latest TGV train from Alstom/SNCF that achieved the world-record speed for mainline railways of 574 km/h in April 2007 3.

ABB compact converters

Propulsion converters are an active link between the transformer and the motors in AC trains. They not only supply the motors with exactly the voltage pattern that is needed in any moment of acceleration, constant speed or deceleration, but they also enable the vehicle to feed back energy to the line during braking. Other types of propulsion converters take a DC voltage input from the catenary (for DC railways, metros or tramways) or use the output of a generator (in diesel-electric propulsion) to feed and control the motors.

ABB has developed a wide range of so called BORDLINE®-CC compact converters that combine propulsion converters and auxiliary converters in one single device[1]. On a regional train, a cabinet the size of a cupboard can hold the propulsion converter, auxiliary converter, battery charger, line filter and the main switch for the power head. The very compact and modular design leaves more space to the passenger and is also most convenient for service 4.

For light rail vehicles, ABB has designed a compact converter that can be mounted on the roof as well as under-floor – a very versatile construction which fits on various vehicles. It features two independent motor inverters and all the other components of a BORDLINE®-CC discussed above Factbox 3.

Smooth ride

All ABB BORDLINE® compact converters employ ABB's standard industrial control platform AC800PEC[2], leveraging cost-efficient long-term support and development. On this platform, simulations in MATLAB/Simulink can be directly translated to the control software. The quality of the propulsion converter control also has a direct impact on travel comfort: A traveler can easily distinguish a vehicle that accelerates impulsively or brakes jerkily because the converters do not perfectly control the motors.

Travel continuity across borders

In Europe, the railway line voltage changes at most of the country borders, often even within one country.

4 Examples of BORDLINE®-CC compact converters for regional trains a and light rail vehicles b

a

b

Factbox 3 Technical data of ABB's compact converter for LRVs 4a

Input voltage:	420 – 900 V DC
2 independent motor inverters with the following **output power per motor:**	
Propulsion:	166 kW
Braking:	345 kW
Emergency brake:	535 kW
Auxiliary outputs with galvanic isolation:	3x 230/400 V 50 Hz, 35 kVA 3x 0…230/400 V, 0…50 Hz, 5 kVA 24/36/72/110 V DC, 8 kW
Size, weight	1600 x 1800 x 430 mm, 550 kg

3 The Alstom/SNCF train with an ABB transformer on board setting the world-speed record. It reached 574 km/h on April 3, 2007.

Networks in Finland, Hungary, Greece, Portugal, parts of France and the United Kingdom for instance are electrified at 25 kV / 50 Hz, as are many other countries in the world including China and India[3]. Mainline railways in Germany, Switzerland, Austria, Sweden and Norway are electrified at 15 kV / 16.7 Hz. Poland, Belgium, Italy and Spain predominantly have 3 kV DC networks, which can also be found in South America and South Africa, while the Netherlands and Southern France are electrified at 1.5 kV DC.

Long-distance travel in Europe and regional travel in cross-border networks rely on the technical capacity of transformers and converters to adapt to different line voltages. It is a great advantage in terms of passenger comfort to be able to remain seated (or bedded in a night train) when the train crosses borders between different electrical grids. Multi-system capability also considerably reduces travel time.

ABB has developed innovative multi-system solutions both for transformers[4] and propulsion converters. Multi-system transformers can handle different input voltages and frequencies. The ABB multi-system front-end converter converts a DC input voltage to an AC voltage for the primary winding of an ABB multi-system transformer; this permits a regular AC BORDLINE®-CC compact converter to be used for both AC and DC input voltages.

The reliability and availability of electric power products on trains have a fundamental impact on passengers' comfort.

This converter is currently used in the regional trains "FLIRT" TILO[5] serving the regions Ticino – Switzerland (AC 15 kV) and Lombardia – Italy (DC 3 kV) 5. In the past, the rail operator TILO had two different locomotive types: one for operation in Switzerland and one for Italy. Trains always had to stop at the Italian-Swiss border to change the locomotive. This procedure took a lot of time. Now, new FLIRT-type trains with ABB multi-system BORDLINE® compact converters permit this border to be crossed seamlessly. Similar equipment has recently been ordered by Südtiroler Transportstrukturen for travel between Italy and Austria.

5 Stadler FLIRT TiLo crosses borders with ABB traction technology.

Reliability, punctuality, availability

Finally, a fundamental aspect of comfort in public transport should be emphasized: the reliability of the service. The reliability and availability of electric power products on trains have a fundamental impact on passengers' comfort.

ABB, with its long experience in the railway industry Factbox 4, not only defends its position as an innovative technology leader, but also puts a strong focus on reliability, quick serviceability, a rugged design, and a long-term commitment to vehicle manufacturers and railway operators.

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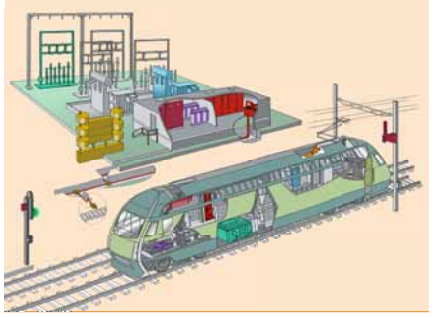
Factbox 4 ABB's history in railways

ABB is a well-known name in the railway industry. While in 1996, ABB Transportation Systems became part of AdTranz (a joint-venture with Daimler-Benz that was later sold to Bombardier), the production of components (such as traction transformers, converters and motors) was retained by ABB. As the forerunner of what are now called "Industry Segment Initiatives," the "ABB Railway Customer Segment RCS" was created in 2005. Through implementation of a focused and coordinated business approach to the railway market, and through improved collaboration between the different ABB-internal units involved, an important business development could be achieved: in 2007, ABB received more than $ 700 million in orders from the railway industry, more than double compared to the start of RCS. Today, ABB enjoys a clear distinction in its market position as an independent component supplier to most of the world's transportation system integrators and vehicle manufacturers.

For rolling stock, ABB's portfolio includes traction transformers, converters, motors, main MV breakers, power semiconductors, surge arrestors and LV products.

For fixed installation, it includes complete power substations, HV and MV products, transformers, power quality solutions, frequency converters, and communication systems for signaling.

For more information, please visit www.abb.com/railway



Footnotes

1) Such converters are further discussed in "The compact converter," *ABB Review* 3/2006, pages 52–55.
2) For further information on the AC800PEC, please see "Design patterns," *ABB Review* 2/2006, pages 62–65.
3) 25 kV AC is used for most new high-speed lines in the world. In many countries, trains may have to additionally operate on networks electrified with 1,500 or 3,000 V DC.
4) ABB's traction-transformers for multi-system trains are further discussed in "Trained to fit," *ABB Review* 3/2006, pages 49–51.
5) FLIRT: "Flinker Leichter Innovativer Regionaler Triebzug" or "Fast Lightweight Innovative Regional Train"; TILO: Treni Regionali Ticino Lombardia, operator of cross-border regional trains between Italy and Switzerland.