ATO and ETCS can work together

AUTOMATION Test running is underway in the suburbs of Praha to demonstrate how the AVV automatic train operation equipment used on Czech Railways can be integrated with the automatic train protection functions provided by ETCS Level 2.

A 22 route-km section between Porícany and Kolin to the east of Praha has been used to test ETCS Level 2 operation. Passenger-carrying trials of dual-fitted trains using AVV were due to commence at the end of January.

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For several years, Czech infrastructure manager SŽDC and national train operator CD have been undertaking trials with the European Rail Traffic Management System, before rolling out ERTMS on the European priority corridors.

In order to gain experience with the operation of ETCS in Czech conditions, the 22 km Poříčany – Kolín section to the east of Praha has been equipped with ETCS Level 2. Around 350 route-km including the line between Kolin and Břeclav has been equipped with GSM-R. These pilot sections form part of ERTMS Corridor E, which crosses the Czech Republic between Děčín, Praha and Břeclav and is due to be fully equipped with Level 2 by the end of 2013.

When this project began, concerns were raised that ETCS might prove incompatible with the AVV equipment developed by AŽD Praha and used for automatic train operation on selected routes. In fact, it has become clear that the two systems are not mutually exclusive, but can be used together to support almost all of a driver's actions during train operation.

For the initial trials with ETCS, CD equipped one of its Class 471 double-deck suburban EMUs and two locomotives — a dual-system Class 362 fitted with AVV and a Class 151 without AVV. With the two dual-fitted trains, CD and SZDC were able to start the compatibility of ETCS with AVV in November 2008. Last year saw the start of test running, with passengers to be carried on the test trains from the end of January 2011. We believe that this is the first practical demonstration of automatic train operation using ETCS Level 2.

ATO and ATP

Developed during the 1990s, AVV (*Automatické Vedení Vlaku*) was put into revenue operation in 2000, and is currently installed on around 300 route-km of the SZDC network; further lines are to be equipped in the next few years. Onboard equipment is fitted to all 65 of CD's Class 471 double-deck EMUs and the one Class 362 being used in the trials. It is also being installed on 37 refurbished diesel railcars of Class 842, 19 refurbished Class 750.7 diesel locos and the 20 new Class 380 three-system locomotives recently supplied by Škoda.

AVV provides automatic driving for

acceleration, cruise control and braking, comparing the actual speed with that requested by the driver and applying traction or braking to control the speed to a precision of 1 km/h, within the envelope permitted by the current braking curve. It can brake the train automatically to achieve both a zero and non-zero target speed with a high degree of accuracy (±1 m of the target point). Together, these functions can help to optimise train running, ensuring that a train reaches the next station or stop on schedule with minimum energy consumption.

Automated systems for target braking and energy optimisation were first tested in the former Czechoslovakia in the late 1960s, using analogue transistor technology. Since then, the technology has progressed through various platforms, including hybrid analogue/digital systems during 1970s and 1980s, but it was not put into commercial operation until a solid-state platform became available in the 1990s.

By contrast the European Train Control System essentially provides automatic train protection, using continuous speed monitoring, and track-train data exchange. This can be intermittent using balises under Level 1 or continuously by GSM-R radio to and from a Radio Block Centre under Level 2.

Reflecting the word 'control' in the title, ETCS can have a much wider interaction with vehicle systems, controlling other devices such as pantographs, circuit breakers or doors, which were outside the scope of traditional signalling systems. Nevertheless, ETCS does not have any form of traction control. In some applications the ATP function is able to request a service brake application rather than emergency braking, although it is not able to control the actual braking rate. The Czech ETCS pilot project does include provision for this service brake output.

The key data transmitted from the track or RBC include the static speed profile (SSP), or permitted line speed, the next signal aspect and a Movement Authority which specifies the target point beyond which the train is not allowed to move. Gradient profiles are also transmitted, and braking parameters are set by the driver before departure. All of this data is processed by the onboard unit to generate a dynamic speed profile and braking curves for the specific train at any particular location.

Cab view from a Class 471 EMU showing the AVV display (centre) and ETCS DMI (right).

If the braking curve is exceeded, a warning, service brake or emergency brake application is invoked. If the service brake is activated, the driver is able to release it once the train's speed has fallen below the braking curve. An emergency brake intervention always brings the train to a stand. Of course, activation of the brake by ETCS is not desirable from an operational perspective, as it can disturb the normal course of train running.

AVV data inputs

In order to control the traction and braking functions, AVV also needs data on train location, including the absolute position and direction of running, as well as signal aspects. These can come from coded track circuits, a national ATP or other 'information points', which could include Eurobalises. All other data are stored in the system memory — either read-only for the route map and timetable or read-write for data set by the driver such as the train number, length, and braking ratio.

Using this information, AVV computes a service braking curve, which the traction controller then follows without overspeeding. When reaching the target point, the brake is released gradually in a controlled process, not 'all at once'. In the case of a non-zero target speed, the braking is adjusted with constant jerk, ensuring that the speed just reaches the desired value at the target point with zero deceleration, allowing the train to continue at constant speed on level track. Because it is controlling the service braking for normal operation, AVV should preclude any risk of the ATP intervening automatically with an emergency application.

AVV also provides several important functions that are not included in ETCS as they are not safety-related, such as braking for a service stop at a station platform and energy-efficient driving. However, although AVV is designed to minimise the possibility

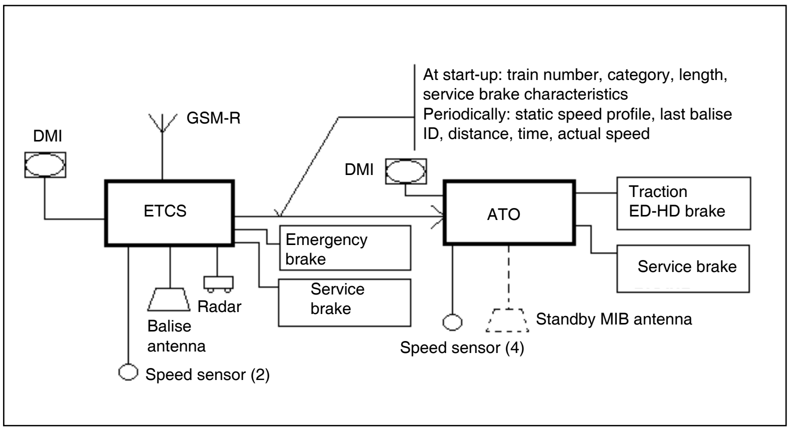

Fig 1. Interface between ETCS and ATO and their respective functions.

of a wrong-side failure, it is not considered a fail-safe system. So trains must also have some form of ATP as well. On the other hand, in the event of any ATP failure, it is better not to switch the AVV off, as it will help the driver to respect speed restrictions. It will also brake automatically at each signal, unless the driver intervenes to confirm that the signal is displaying a proceed aspect.

Safety and economic benefits

ETCS and AVV complement each other very well. The primary duty of any train protection system is to ensure safe operation, and the economic benefits of ETCS, other than interoperability, can only be estimated in terms of the savings from preventing accidents. However, any ATP intervention is undesirable from the perspective of energy consumption, as it disrupts smooth operation.

In contrast, the automatic control offered by AVV is intended to make more efficient use of track and train, delivering quantifiable savings. Keeping train speeds close to, but just below, the ATP braking curve avoids unnecessary intervention with a positive effect on energy consumption. AVV also relieves the driver of many routine functions, giving more time to watch for abnormal conditions, such as trespassers on the line, vehicles on level crossings, or damage to the track or overhead equipment.

Onboard equipment cabnet of a dual-fitted Class 471 City Elefant EMU, located in the vestibule.

System co-ordination

Both devices complement each other functionally, for instance by using the ETCS transmission channel to transfer AVV data instead of the current magnetic transponders. This would allow the transponders to be replaced by Eurobalises, once all vehicles have been equipped with ETCS, or at least the antennae and balise transmission modules. A similar sharing of data transmission by ATP and ATO is already found in the LZA system used on Praha metro Line A.

Comparing the driver's activities during a typical journey between two stations (Table I) shows that the use of AVV does not affect any of the ETCS functions. But equally, ETCS does not decrease the driver's workload. Paradoxically, simulations and trials suggest that with ATP the driver must absorb more information so the workload actually increases.

On a dual-equipped train, AVV must control train operation in such a way as to prevent an unnecessary ETCS intervention. This is ensured best by using common data, avoiding the risk of an intervention being caused by the two systems evaluating the vehicle's location or speed differently. AVV can also use the same train parameters as ETCS when calculating braking curves. But continuous transmission of the line speed profile is also required, as AVV uses this to control train operation.

Pilot project

To confirm the compatibility of AVV and ETCS, CD, SŽDC, AŽD Praha and ETCS supplier Ansaldo STS are currently undertaking trials with the two dual-fitted trains on the pilot route.

The Class 471 double-deck suburban EMUs, of which 65 have been delivered since 2000, have been equipped with AVV from new. These EMUs are designed for 140 km/h operation on lines electrified at 3 kV DC. Only minor modifications to AVV were needed to work with ETCS, such as fitting a processor card that can support CAN communication and uploading the relevant software. A CAN-to-RS422 converter was installed in the ETCS rack to provide the link between the two systems.

The dual-system Class 362 used in the trials was built in 1990 to a design dating from 1981. These locos were originally equipped with an analogue automatic speed control, but pilot loco No 362.166 was converted to digital control and fitted with AVV, releasing space in the electronics compartment to install ETCS equipment. This modification work took around three weeks.

The two systems are connected using an RS422 serial line, permitting continuous transmission of information from ETCS to AVV for the line speed profile, actual speed, and train location. Variable train parameters, such as the train number and brake profile, are only downloaded at the start of a trip or on request from the AVV.

As well as designing the interface between the systems, in terms of both

Table I. Driving activities overseen by ATO and ATP

	ETCS without AVV		ETCS with AVV		
	Driver	ETCS	Driver	AVV	ETCS
Ordering train departure			x		
Control of moving off	x	SC		x	SC
Accelerating to full speed	x	SC		x	SC
Braking for speed restriction	x	SC		x	SC
Running at restricted speed	x	SC		x	SC
Check rear of train is clear of restriction	x	SC		x	SC
Coasting to allow 'just in time' arrival	x			x	
Station entry at restricted speed	x	SC		x	SC
Braking	x			x	
Stopping at platform	x			x	

x - executes; SC – checks safety

Far left: **AVV display in speed control mode.**

Centre: **Class 362 locomotive equipped with temporary ETCS DMI.**

Right: **A Skoda Class 380 locomotive with provision for integrated AVV and ETCS display screens.**

hardware and software, another challenge has been to develop a suitable driver display, given the shortage of space on the control desk. All of the pilot trains have been temporarily fitted with free-standing ETCS DMIs.

On the Class 471s, the AVV display is an integral part of the control system. For the Class 362 loco, a new AVV train management screen replaces the conventional instruments, showing the usual voltage, speed and status data in manual mode and the train control data in AVV mode. This includes the required and actual speeds, braking curve, target speed and distance, plus signal and station locations. The AVV screen is also used for diagnostics and data input at start-up.

The communication between the two systems was mainly tested during the field integration tests, and as is usually the case with different subsystems some problems were found. These were mostly minor, covering such issues as wrong number formats, a mismatch of physical units, or using different origins for the two distance measuring devices. The issues are now all closed, and the latest runs have proved that the two systems are well integrated.

The test vehicles still have a complete set of AVV equipment, including magnetic transponder sensors, because only a short section of the pilot route is equipped with ETCS. Having both antennae in operation allows us to compare the accuracy of train location by both systems, and observe any delay in transmitting the balise information from ETCS to AVV.

We are now undertaking various track tests to evaluate the operation and functional interfaces between the two systems. The next step is the start of trial operation with passengers, which was expected to start at the end of January [*please confirm if this happens*]. If all goes well, CD expects to seek permission from the Railway Authority for commercial operation after about nine months of tests. Meanwhile, the fitting of ETCS to other rolling stock is expected to get underway soon.