ERTMS/ETCS in Asia and Australia

Clarence Rajan Paramasivam
Bach. I.T. with Distinction, Grad. Cert. BA., M.I.R.S.E
Bombardier Transportation Signal (Bangkok, Thailand)

SUMMARY

The purpose of this paper is to provide a description of European Rail Traffic Management System (ERTMS) / European Train Control System (ETCS) in Asia and Australia. It will not describe the now well known technical concept of ERTMS/ETCS, but rather describe the transition from European standardisation initiative to global Automatic Train Protection (ATP), slowly finding its niche in Asia and Australia along with the experiences of Bombardier in making this transition a reality. Bombardier has over 25 years of experience in balise based Automatic Train Protection and the ERTMS/ETCS standard has strong links to the Bombardier legacy balise systems. Bombardier was the pioneer for ERTMS/ETCS Level 1 with its commercial pilot line in operation in Switzerland in 2002 based on Release 5A specifications. Since then Bombardier has successfully continued to work in UNISIG with the development of the ERTMS/ETCS standards and deliver ERTMS projects within Europe. In parallel it has progressed to take this European based standard into Asia with an industry first ERTMS Level 1 project in Taiwan, an ERTMS Level 1 and Level Specific Transmission Module (STM) project in South Korea, an ERTMS Level 2 and Level STM project in China and now the recent successful RailCorp ATP Pilot Trial with ERTMS Level 1 on a section of the Blue Mountains line, in west Sydney, Australia. With the significant experiences gained in Europe and market entry projects in Asia, Bombardier is at the forefront of pushing this once European vision as the ATP benchmark for Asia and Australia.

1 INTRODUCTION

Bombardier has been working with the implementation of communication based signalling and ERTMS for mainline applications since the mid 1980’s. ERTMS was developed to standardise communication based signalling within Europe. The benefits ERTMS provides to the operator are interoperability between suppliers, improved safety and the ability to optimise traffic capacity. These benefits are now being sought after in Asia with several projects underway and most recently in Australia with the ATP Pilot Trial on the Blue Mountains line.

2 EUROPEAN ORIGINS

Based on an EU initiative and financial support, and a combined effort from European Infrastructure Owners and Railway Operators, the Railway Industry led by the six members of UNISIG, have taken ERTMS/ETCS from concept to commercial operation. What started as a Master Plan for Trans-European high-speed rail network in 1990 is now a more stable Technical Specification for Interoperability. The latest technical baseline, ERTMS/ETCS Class1 SRS 2.3.0 is now sought after in many European railway tenders as the years of development, test and feedback have led to a more accepted standard for Railway Infrastructure Owners and Operators.

Since 2005/2006, ERTMS/ETCS has been in commercial operation in various European countries including Germany, Italy, the Netherlands, Spain and Switzerland. See Figure 1 below for a snapshot of Bombardier ERTMS/ETCS projects.

Figure 1

Bombardier was the pioneer for commercial ERTMS/ETCS Level 2 with its commercial pilot line Olten-Luzern in operation in Switzerland between May 2002 and November 2003. The test results showed performance levels of 99.6 % availability
(see Figure 2) and proved a valuable exercise in defining the GSM-R standards.

Also met were SBB’s timetable requirements for passenger trains - 95% of all trains should be less than 5 min delayed and 75% of all trains should be less than 1 min delayed. See Figure 3 below.

ERMTS/ETCS has significantly advanced in terms of stability and many interfaces in the wayside system are already standardised, such as the “airgap” (the protocol for information exchange between wayside and train) or the interface between LEU and Eurobalise. However important interfaces such as the Radio Block Centre (RBC) RBC-RBC interface and the RBC-Interlocking interface remain still to be standardised.

3 GLOBAL ATP – ERTMS/ETCS IN ASIA

Although initially conceived for Europe, the associated benefits of the ERTMS/ETCS concept have attracted the Railway Infrastructure Owners and Operators to apply this concept outside of Europe.

The key benefits of ERTMS/ETCS include:-

- Interoperability - train and track Europe-wide
- Interoperability - cross border traffic
- Integrates with existing ATP
- Multiple choice of supplier = stronger position for infrastructure owners and railway operators
- Enables high-speed traffic
- Reduced railway operation costs
- Supports other trainborne functions
- Safety via ATP with in-cab signalling
- Reduction of installed base = reduced maintenance
- Migratable solutions
- Termination of investment in outdated ATP and signalling systems
- Cost saving for both the railway and society resulting from reduced incidents.

3.1 Taiwan

With these key benefits in mind, Bombardier entered an industry-first ERTMS contract in Taiwan with the Taiwan Railway Administration (TRA). The ERTMS was successfully commissioned and has been in commercial operation since 2005.

3.1.1 Scope of delivery

To replace the old train warning and train stop system supplied by Bombardier from 1979 onwards. The project required in-cab signalling for 23 different types of vehicles and in total 768 vehicles were fitted with the onboard equipment for ERTMS Level 1. The wayside consists of 1,200km of track and 156 stations. Approximately 13,000 balises and 2,000 Lineside Electronic Units (LEUs) have been installed on the wayside across the entire island network, see Figure 4. Bombardier was responsible for the detailed design of the interfaces to both lineside and
vehicle equipment including the tilting train function for the trains delivered by Hitachi for high speed traffic and the interface to the onboard Passenger Information System and Protective Radio System. As well as quality assurance, Bombardier has had to prepare a consolidated safety case for the equipment and commissioning programme. Also undertaken was driver training, for which 13 simulators were supplied.

The TRA application incorporates, the Bombardier ERTMS/ETCS Level 1 solution with an ATP system that monitors whether a train driver is complying with speed restrictions, and actively brakes the train if there is a risk of the permitted speed and movement authority being exceeded. The onboard system receives data transmitted from trackside equipment, and dynamically generates safe speed and distance profiles, which are then presented on the cab-mounted driver machine interface (DMI). Train speeds are designated in four bands. Within the permitted speed band, the train can operate at any speed up to the line limit of 130 km/h. Above this is the warning speed band, where the ATP provides audible and visual overspeed warnings to the driver; these disappear as soon as the speed is reduced below the line limit. Should the driver fail to respond to the warning and keep accelerating into the next band, the ATP will apply the service brakes. Once the speed drops back into the permitted band, the driver is free to release the brakes. Should the train speed continue to rise, however, the ATP will apply the emergency brakes and bring the train to a complete stop. This emergency application cannot be over-ridden by the driver.

TRA expected the installation of ATP to increase line capacity and reduce journey times, as trains will be able to approach stop signals faster. Normally a driver approaching a signal with a caution aspect would have to slow down to a predetermined speed limit before the yellow signal, and then continue at this lower speed to stop at the red aspect. The Bombardier solution uses a distance-to-go technology which calculates the optimum braking curve needed to comply with the stop aspect. When a train approaches a caution signal, the ATP balise sends information about the target distance to the stop signal. The trainborne equipment uses odometry inputs to measure the distance travelled from the balise and establishes the correct distance from the signal to initiate the braking curve. As with the clear line situation, the ATP generates a target warning curve, automatic service brake curve and emergency braking curve which will ensure that the train is brought to a standstill in front of the red signal.

The onboard display dramatically increases the amount of relevant information available to the driver, so that the train can be driven more efficiently, and with better headways. The display shows, among other things: stopping distance, current speed, maximum allowable speed, expected limitations, operating mode, and error messages. The onboard system interfaces with the train propulsion and brake systems, as well as other onboard systems, and interacts with them automatically in case of danger.

The trackside equipment consists of fixed balises (static content of telegram), and controlled balises (dynamically changing content of telegram). Both sets of balises are read by the train’s onboard antenna when the train is passing over them. The controlled balise transmits different telegrams depending on the signal aspect. The controlled balise is connected to the Line Electronic Unit (LEU) which interprets data from the signals and interlockings.

3.1.2 Challenges faced and how they were solved

The sheer logistics of a project of this size ensured several challenges were encountered along the way. One of the key challenges faced was to deliver one onboard solution for 23 different vehicle types including DMUs, EMUs Diesel Locos, E-locos etc. This was primarily solved through the benefit of Bombardier’s modular, distributed onboard system. The platform has a distributed architecture where all communication between units is handled via a serial data bus. All hardware units are self-contained in
their own enclosures and no racks are needed for mounting. The units require no forced cooling. As the platform has a distributed architecture, where the hardware units are interconnected by a serial data bus, these units can be mounted directly onto the vehicle, which means that equipment racks or cabinets are not necessary. The I/O units may be connected directly to the vehicle battery and be mounted close to the external equipment they are connected to, avoiding complicated scheming and distribution of cables. This solution enabled a variety of a vehicle installation design to serve the variety of vehicle types whilst maintaining and inherent, singular onboard solution. See Figure 5 for an illustration of the distributed onboard architecture.

![Figure 5](image)

3.2 Korea

When the Korean National Railroad (KNR) decided to buy high-speed trains, they realised there was a need to improve the train operation system of Gyeongbu Line (Seoul-Busan) and Honam Line (Daejon-Mokpo) from the existing ATS (Korean legacy ATP system) to an ERTMS/ETCS Level 1 cab signaling system to allow high speed and high density rail operation. See Figure 6.

3.2.1 Scope of delivery

The scope was to deliver an ERTMS/ETCS Level 1 system on a pilot section of 33km length and 8 vehicles of 5 different vehicle types should be equipped for this pilot section. Once the pilot section was commissioned, the roll out of the remaining locos and wayside (405 locos and 750 km) could begin. In combination, the pilot line and mainline scope covered 760 kilometres of track, 78 stations, 413 vehicles, 7000 balises, 2260 complete LEUs. Further to the scope was another localisation aspect which on top of local engineering and joint development of the Driver Machine Interface (DMI), Recording Unit (RU) and STM, also included local assembly of Balises and local production of Lineside Equipment Units (LEUs.). Another requirement was an increase of the maximum speed of KTX trains from 150 km/hr to 180 km/hr. Vehicles have now been in commercial operation since 2006 running in ERTMS/ETCS Level STM mode running ATS, and proved to be a significant design challenge and substantial testing and commissioning work resulted as site data (e.g. location of signals, points etc) over 1200km track network in reality did not always correspond to the documentation at hand.

Another key challenge was the significant localisation aspect often encountered when delivering projects in Asia. For the Taiwan project, Bombardier had to deliver the project with 33% local content. This placed extra overhead on the project management and technical management to ensure distributed design remained integrated and efficient. That said because of cultural differences and often a language barrier in Asia, it is an advantage to have a local (signalling) company as a partner, when implementing large scale ERTMS/ETCS projects with most advantages seen in training and condition of local operators and drivers.
commissioning of ERTMS/ETCS Level 1 is expected before end 2008.

Figure 6

3.2.2 Challenges faced and how they were solved

Although the Taiwan project was still running, the Korea project provided a natural progression in functionality as it built on the functionality of Taiwan with the addition of ERTMS/ETCS Level STM to enable the trains to run on the legacy ATS equipped lines and transition between ATS and ERTMS/ETCS Level 1 equipped lines.

As part of the goal to achieve a high technical transfer it was also agreed that following the commissioning of pilot section, BT would train the consortium KNR’s staff in application of the wayside design manual and would train KNR’s personnel in the installation, test and commissioning activities on the pilot section. The purpose of this was so that KNR shall be able to undertake all activities for the main section themselves after the Transfer of Technology and training packages had been delivered. This will lead to KNR being able to maintain, update and extend their rail signaling network without the need of Bombardier. Similar to Taiwan, the project had to be delivered with 60% local content which posed associated design and manufacturing challenges.

3.3 China

Towards the end of 2007 Bombardier entered the High Speed Line market in China in the WuGuang province. Bombardier will deliver an ERTMS/ETCS Level 2 and Level STM project to the China Railway Signalling and Communications Corp (CRSC) and its customer the Chinese Ministry of Railways (MOR). See Figure 7.

3.3.1 Scope of delivery

The project requires the onboard installation of 120 vehicles of 2 different train types that have a maximum speed of 350km/h. The wayside consists of 1000km of doubletrack between Wuhan and Guangzhou with 9 RBCs to be installed and Computer Based Interlockings (CBIs) to cover 18 stations and a Centralised Traffic Control (CTC) system with local control facilities. Further to this a simulation and test laboratory have already been provided. It is expected that commissioning of the system for commercial operation will start in 2009.

Figure 7

3.3.2 Challenges ahead
Like Korea built on the functionality of Taiwan, China provides a natural progression in functionality from the ERTMS/ETCS Level 1 and Level STM to ERTMS/ETCS Level 2 and Level STM. Again a significant transfer of technology and localisation aspect will demand additional challenges as faced in previous projects in Asia. Further, the joint development of the DMI and STM will place strong previous projects in Asia. Further, the joint

4 GLOBAL ATP – ERTMS/ETCS IN AUSTRALIA

Could the following incidents in Australia have been avoided with an ERTMS/ETCS ATP system in place? – there are many in the railway industry who believe so.

- October 13, 2002 – Benalla level crossing collision, Victoria, Australia. A heritage train hauled by K class steam locomotive K 183 collided with a B-Double truck that failed to clear the level crossing. The impact caused the locomotive to derail, rolling onto its side. Of the four people in the cab at the time of the collision, three were killed and one critically injured.

- January 31, 2003 – Waterfall train disaster, Waterfall, New South Wales, Australia: The driver of a southbound passenger train suffered a heart attack and died; the train sped out of control and derailed on a curve, overturning several cars and killing 6 passengers.

- February 3, 2003 – A Broadmeadows train rolled away & crashed, Melbourne, Victoria, Australia: An unmanned electric suburban train rolled away from Broadmeadows Station and ran for 16.848km at speeds in excess of 100kmh through many pedestrian & level crossings before crashing into a stationary Diesel passenger train at Southern Cross Station derailing both. More through luck than anything else, no injuries resulted from this incident.

- November 15, 2004 – Bundaberg Tilt Train Derailment, Berajondo (near Bundaberg), Queensland, Australia: The world’s fastest narrow-gauge train derailed at 108 km/h. No-one was killed or permanently injured. The accident was caused by the train travelling too fast on a curved line.

4.1 Railcorp

The RailCorp ATP Pilot Trial is an experimental ETC installation on part of the Blue Mountains line. The line contains three evaluation track sites, each of about 12km (see Figure 8). The sites are fitted out with ERTMS/ETCS Level 1 wayside equipment by different UNIFE suppliers. The project also included three 4-car V-Set EMUs being fitted with onboard ETCS equipment by the suppliers.

InterOp is the Joint Venture (JV) between Bombardier Transportation Australia (BTA) and Westinghouse Rail Systems Australia (WRSA) that was formed to offer the best supplier combination for RailCorp in their ATP Pilot Trials. The work split within the JV is relatively transparent with Bombardier responsible for fitment of the InterOp V-Set train and Westinghouse responsible for the wayside engineering and fitment.

![Figure 8](image)

4.1.1 Scope of delivery

InterOp was required to fit ERTMS/ETCS Level 1 on the Blue Mountains line between Wentworth Falls and Katoomba, an 11km section of double track and a V-SET train type was defined consisting of two Motor cars and two Trailer cars with one EVC in each Motor car. In summary the scope of delivery included 66 Balises in the de-centralised LEU Area, 13 Parallel LEUs in the centralised LEU Area, 6 Serial LEUs + 1 Central LEU Concentrator, 1 Dynamic TSR Terminal, 1 Dynamic TSR Vital Management System, 1 Technician’s Terminal (Moviola), 1 Remote Access PC and 2 onboard ATP systems.
4.1.2 Lessons Learnt

- Tie down project scope early to allow order of long lead time equipment as early as possible
- Comprehensive surveying is essential, existing plans cannot always be relied upon
- PC equipment ideally need UPS back-up
- More accurate measurements from the vehicle survey would have avoided additional installation reviews. Many components e.g. antenna and Doppler radar frame, ATP locker, ATP rack did not fit the vehicle
- The mechanical design of ERTMS/ETCS Onboard installation can be improved (SIFA valve and Pressure Switch should not be located outside the train)
- All wiring checks normally will be performed after the completion of installation work in order to mitigate the electrical installation errors. But, due to time constraint, the wiring check was not carried out resulting in lot of wiring errors slipping through to the testing phase.

4.1.3 Conclusion

The tests were executed according to plan, in general and the main objectives were achieved. The defined ETCS functions were demonstrated on the line. In most cases the functions were successfully demonstrated. The deviations from test specifications noticed were often minor. During the tests, the human factors expert was present most of the time. A lot of data was recorded about the impact on the drivers. The evaluation of this was outside the scope of this project, but it was noticed that the drivers would have benefited from a more thorough ETCS education prior to the trial runs.

The Interoperability of ERTMS/ETCS was proven. The initial problems found between different suppliers had more to do with engineering errors and misinterpretation of requirements. The safety of the system was proven, specifically with the over-speeding and target braking test cases. A full capacity evaluation of the overall traffic situation in the whole network was not done since the tests were performed on a low traffic density line with long block sections and only one vehicle at a time was available. The vehicle was capacity tested for braking curves and other impacts on the time table.

The pilot trial is considered by both Railcorp and InterOp to be a success. The goal of proving that ERTMS/ETCS Level 1 could be used to improve safety on the RailCorp network without affecting performance has been demonstrated. Also, full interoperability has been demonstrated between different suppliers. Common application rules have been elaborated and tested for a future network rollout. This gives RailCorp an excellent baseline for any ERTMS project in the future.

5 RECOMMENDATIONS

The application of ERTMS/ETCS in Asia has been proven and continues to flourish in new markets within Asia.

Whilst not in commercial operation, the success of the Railcorp ATP pilot trial runs has provided a solid grounding to further evaluate the benefits ERTMS/ETCS could bring to Australia in terms of safety, capacity and interoperability between potential suppliers. From the experiences Bombardier has gained in multiple project delivery in Europe and market entry into Asia, the following recommendations are made for furthering the ERTMS/ETCS introduction in Australia:

- Continue Collaboration Development Agreement process to iron out any open requirement and interoperability issues remaining from the Railcorp ATP trial project
- Further discussion and closure of available ERTMS/ETCS features together with RailCorp and drivers
- Joint development of operational scenarios to create common understanding of system functionality/behaviour particularly for fall-back modes
- Preparation of SRS based on operational scenarios, simulations and customer functional requirements
- Bring in assessors and approval authorities early in the process
- A full capacity evaluation of the overall traffic situation
- Further training recommended via the use of simulators to prepare drivers for the introduction of ERTMS/ETCS and in general ATP on driving style
- Wider review of application rules and update of trial equipment to facilitate validation of any changes for network rollout

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• Setup of independent LAB to verify interoperability on site which has proven to be very costly onsite
• In order to minimise future risks with respect to functionality interpretation, it is desirable that a limited line section comprising of 2-3 stations and representative vehicle types could be installed as early as possible as in Railcorp, Taiwan and Korea projects
• Performance objectives, which need to be reached prior to switch-over, should be agreed and measurement method and process elaborated
• Installation of Wayside can proceed on a number of Stages independently but needs to be well planned so that the trains are sufficiently equipped to operate on commissioned sections of track, if an STM is to be avoided
• It is possible to install balises, LEUs and RBC with minimal operational impact as long as the onboard system is not switched on.
• NCRs will be generated for a period of time after the system is live, as real live performance will always stress the system more than testing scenarios performed off-line; a reasonable deployment of NCR correction needs to be accommodated in the project schedule
• Bombardier solutions allow that the Onboard and LEU installation can be facilitated by a pre-fabricated ATP board and pre-assembly of LEU racks/cabinets with power supply
• Accurate vehicle documentation and survey can minimise Rolling Stock Unavailability according to an aggressive schedule as shown below:
  Day 1: Install Cables, tachometer, antennas and driver panel
  Day 2: Insulation and continuity test of cables
  Day 3: Installation of ETCS panel and all other components, software download, calibration, power-up etc.
  Day 4: Installation test and commissioning of each vehicle
• Preventive Maintenance schemes and checks such as visual inspections of equipment, balises, encoders, cabinets, cables, earthing, etc.
• For the RBC, no periodic adjustment is needed to sustain continuous operation. The system supervises main and standby operational status continuously. In case of malfunction, the report will be sent automatically to the control center. However, it is recommended to check, on an annual basis, that stand-by equipment is operational. Periodic cleaning is also recommended as this may help to prevent system malfunction.
• For Onboard ATP an inspection every 3 months is recommended, for example to facilitate wheel size data check and if needed modifications of train parameters to suit. Regular check of antennae position and cleaning of antenna when dirty to keep its transmission capability likewise.

Bombardier has proven experience in Asia and Australia of supplying ERTMS/ETCS solutions with an inherent ATP system that provides a standardised foundation for any future enhancements and capacity improvements. In today’s economical and environmental climate, this is a key for meeting customer and public expectations. ERTMS/ETCS has proven and will continue to provide railway infrastructure and operators in Asia and Australia with the essential building blocks to improve capacity and still provide and at times increasing the level of safety.

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