ERTMS/ETCS - Indian Railways Perspective

P Venkata Ramana, IRSSE, MIRSTE, MIRSE

Abstract

European Railway Traffic Management System (ERTMS) is evolved to harmonize cross-border rail connections for seamless operations across European nations. ERTMS is stated to be the most performant train control system which brings significant advantages in terms of safety, reliability, punctuality and traffic capacity. ERTMS is evolving as a global standard. Many countries outside Europe - US, China, Taiwan, South Korea and Saudi Arabia have adopted ERTMS standards for train traffic command and control.

1 Introduction

Signalling component of ERTMS has basically four components - European Train Control System (ETCS) with Automatic Train Protection System, Global System GSM-R, European Traffic Management Layer (ETML) and European Operating Rules (EOR). ETCS is not a signalling itself, but provides a layer over existing signalling. It has 5 application levels and 16 operating modes. Each application level define level of protection to trains. GSM-R is though a separate element, ETCS make use of GSM-R for its voice and data communication. ETCS has two components - Lineside Equipment (LSE) and Onboard Equipment (OBE). Basic ETCS Application Level is Level 0 where locomotives have been fitted with OBE and no LSE has been provided. In Level 0, ETCS will do limited monitoring - monitoring of Max Speed. Level 1 is where OBE on Locomotives and LSE are provided. In Level 2, GSM-R over a fixed network is required in addition to OBE and LSEs and Lineside signals are not mandatory. Level 0, 1, and 2 work on fixed block concept where train sections have been demarcated with signals or signages. In Level 3, moving block in place of fixed block will be mandated. Level STM is meant to provide interface to trackside existing national protection systems AWS, TPWS & TPWS+ (UK) and OBE.

Line-side Equipment consists of Balises and Lineside Electronic Unit (LEU) for transmitting the information from trackside to Locomotive Onboard Equipment. LEU is an interface between lineside signal and Balise. Balises are passive devices and gets energised whenever Balise Reader fitted on Locomotive passes over it. On energisation, balises transmits telegrams to OBE. Telegram may consist of information about aspect of Lineside Signal, Gradients etc., Balises are generally grouped and unique identification will be provided to each balise. It helps to detect the direction of train. There four types of balises exist based their usage - Switchable, Infill, Fixed and Repositioning balises. Switchable balises will be provided near lineside signals and they transmit aspect of lineside signal, permanent speed restrictions, gradient information etc., Infill balises are provided in advance of signals to convey aspect of lineside signals earlier than Switchable balises. Fixed balises convey information in regard to temporary speed restrictions and Repositioning balises provides data corrections. Balises transmit data in long or short telegrams and those pertaining to direction. They are of two types - standard and reduced. Standard balise can transmit data to trains running up to 500 kmph without any loss, whether telegram is of long or short one. Reduced balise can transmit data to trains running up to 500 kmph without any loss for shot telegram and 300 kmph for long telegram.

Figure 1: ETCS Lineside Equipment

Balises provides spot based update of information. The limitations of a spot-based update of signalling information is that the signalling information held by the train and displayed to the driver is only as good...
as the last transmission spot that the train passed, that is, at the last signal. There are other alternatives for transmitting telegrams form Lineside to Onboard. They are Euro Loops and Radio Infill balises. They overcome limitations of Balises. Format of telegrams will be the same irrespective of source of delivery. Radio Block Center (RBC) are required to transmit Movement Authority (MA) and End Of Authority (EOA) in Level 2 and 3 over fixed mobile infrastructure to OBE. OBE provides train position information to RBC. RBC interfaces with trackside interlocking.

At the heart of Onboard Equipment is the European Vital Computer (EVC). Single Loco or Multiple Locos can have one set of onboard equipment or individual. EVC supervises train movements, takes inputs from balise, radio infill or loop via Balise Transmission Module or Loop Transmission Module, odometry, driver, standard information; provides output to Man Machine Interface (MMI), braking through Train Interface Unit (TIU), train position and integrity to RBC.

![Figure 2: ETCS OnBoard Equipment](image)

TIU interfaces with braking system, train control (raising, lowering of pantograph), engine control (cut power during braking to reduce tractive effort), cab status information, master control (position of direction controller). Balise Reader energises Balise to enable it to transmit telegram to trains via Balise Transmission Module or Loop Transmission Module.

MMI provides information to driver in regard to Distance To Go (DTG) , Max Speed, Point of braking to avoid intervention. Tachometers, Speed radars provides speed and distance travelled with +/− 5m +5% accuracy. Driver’s Reminder Appliance (DRA) reminds the driver about pending task. Isolation Switch will detach breaking function from EVC. Specific Transmission Module (STM) provides interface to National Train Protection systems such as AWS, TPWS etc.

Juridical Recording Unit (JRU) records all events, which is like a black box, and useful in investigation and to determine cause of train accident. One has to note that ETCS is a data driven system. It ensures data and message consistency at every stage. However, it can not check the validity of data. So, inaccurate data will be major hazard for ETCS.

## 2 Determination of Location

OBE determines Train Speed and also its location. The same will be conveyed to TSE. It conveys Train Location/Position relative to Balise group. It takes into account distance between front of train and antenna. Accurate positioning of balaise group is important. OBE ensures that train does not exceed speed profile, which is determined from odometry and balise group location - 100% not accurate. Estimated Position may not be Actual Position of the train on the ground. Two types of errors may crop up - Underread or Over-read. For Safety related reasons, train utilises worst case odometry error. To manage inaccuracies, OBE calculates a tolerance window either side of estimated position of the train. OBE determines train location with respect to EOA and Supervised Location (SvL). SvL may be Overlap (OL), Danger Point (DP) or EOA. OBE will estimate the distance to travel before reaching the EOA based on its estimated position and the known location of the EOA. Due to inaccuracies in odometry, the estimated distance to the EOA will not necessarily be the same as the actual distance to the EOA. In order to ensure that the train never exceeds the actual SvL, the ETCS onboard equipment assumes worst case underreading odometry error (that is, it supervises the train based on the maximum safe front end). The assumed distance to the SvL, that is, the one the train supervises to, is therefore on the approach to the actual SvL. On the other hand, the EOA is supervised assuming no odometry error, as this location is not as critical as the SvL. The supervision against the assumed location for the EOA therefore matches the trains estimated EOA location.

As an example, consider the following:

a) A train that passed a balise group in the last 100 m

---

GE/GN8605 ETCS System Description Issue One: February 2010 Railway Group Guidance Note
ERTMS/ETCS - Indian Railways Perspective

b) The location of that balise group is known to an accuracy of 5 m

c) The trains odometry is accurate to (5 m + 5\%) of distance travelled since balise group. Note: the fixed 5 m tolerance is intended to cover the longitudinal uncertainty of the balise reader in detecting the balise reference location.

Figure 4: Safe Max/Min Front/Rear End

The calculated odometry error will be (5m+5m+5\% of 100m), that is, 15 m. The worst case under-reading odometry error will, therefore, be 15 m. However, the actual odometry error could be under-reading by only 2 m. Figure 5 shows the relationship between the actual locations and the assumed locations for both the EOA and the SvL.

It can be seen that:

a) In neither case does the assumed location of the EOA match the actual location of the EOA on the ground nor does the assumed location of the SvL match the actual location of the SvL on the ground.

b) The assumed SvL will never be beyond the actual SvL, even for a worst-case under-reading error; it uses the maximum safe front end of the train.

c) For an under-reading error, the assumed EOA will be beyond the actual EOA.

d) For an over-reading error, the assumed EOA will be on the approach to the actual EOA.

e) The resultant effect is to bring the assumed EOA and assumed SvL closer together by a value equal to the calculated worst-case odometry error.

Second Component of ETCS is GSM-R. GSM-R is a radio system which provides voice and data communication between the track and the train. It is based on standard GSM using frequencies specifically reserved for rail application with certain specific and advanced functions. It provides Advanced Speech Call Items (ASCI) specific to Railways namely, Location Dependent Addressing (LDA), Functional Addressing, Voice Group Call Services (VGCS), Railway Emergency Call, Enhanced Multi Level Precedence & Preemption (eMLPP).

3 Future Communication

GSM-R standard has been evolved in 2000 to replace all analog systems then in use and to provide cost-efficient and interoperable standard for communication between trains. It is the only standard for digi-
eral railway communication and today 1,00,000 route kilometers have been covered in Europe, Asia, Australia, North Africa. Industry has given commitment to support the GSM-R technology until at least 2030.

Two developments are taking place - one is LTE-R that is poised to replace GSM-R and the other - UIC is formulating specifications for Future Radio Mobile Communication System (FRMCS) as a successor or GSM-R².

LTE characterises high speed, high security and high-bandwidth capacity allow it to carry voice and data for train control, on-board video surveillance and information services for passengers on a single IP network. It has latency as 10 milliseconds allowing for support of time-sensitive applications and providing quality of service management. It can be deployed in many different frequency bands and has multiple features related to encryption and authentication for security purposes.

4 Relevance of ERTMS/ETCS on Indian Railways - Context

Indian Railways (IR) is having vast network of 60,150 route kilometers under Broad Gauge (BG). 23,555 route kilometers have been electrified. It carried 8,107 million passengers and 1,108 million tonnes of freight in the year 2015-16. It has 11,122 locomotives. The existing trunk routes are highly saturated, line capacity utilization varying between 115% to 150%. Average speed of passenger trains is 35 kmph and that of freight trains is 25 kmph on mainline. Average speed of trains in suburban sections is 50 kmph. The average speeds are low because IR carries mixed traffic.

In order to improve average speeds of train, trains have to run at higher speeds. One of the issues with high speeds is sighting of lineside signals. It will be difficult to sight the lineside signals if speed exceeds 160 kmph. For high speeds, cab signalling (displaying aspect of lineside signal in the driver cab) is required. Some railways tried to achieve this with additional aspects with lineside signals, but however, it works out with highly trained loco drivers that too upto 200 kmph. Next requirement to improve higher speeds is to make train running safe. It is known fact that how much amount of interlocking among signalling functions is built, if the driver passes the signal on danger aspect, the safety of the train jeopardises. Also, the number of lineside signals have been proliferated especially on high density trunk routes on account of introduction of second distant signalling, interlocking of level crossings gates and intermediate block signalling.

Introduction of Dedicated Freight Corridors may divert freight traffic to some extent but still mainline remains mixed traffic. One more requirement of higher speeds is to make train running safe. It is known fact that how much amount of interlocking among signalling functions is built, if the driver passes the signal on danger aspect, the safety of the train jeopardises. Also, the number of lineside signals have been proliferated especially on high density trunk routes on account of introduction of second distant signalling, interlocking of level crossings gates and intermediate block signalling.

Auxiliary Warning System (AWS) prevents SPADs with help of trackside magnets passing aspect information of lineside signal from track side signals to locomotive. Train Protection Warning System (TPWS) with LSE and OBE provides both in cab signalling and protection against SPADs. TPWS protects trains not only from SPADs, but also from over-speeding, rollaways, reversing, standstill etc.

Introduction of Dedicated Freight Corridors may divert freight traffic to some extent but still main-
line remains mixed traffic. One more requirement of higher speeds is to make train running safe. It is known fact that how much amount of interlocking among signalling functions is built, if the driver passes the signal on danger aspect, the safety of the train jeopardises. Also, the number of lineside signals have been proliferated especially on high density trunk routes on account of introduction of second distant signalling, interlocking of level crossings gates and intermediate block signalling.

Auxiliary Warning System (AWS) prevents SPADs with help of trackside magnets passing aspect information of lineside signal from track side signals to locomotive. Train Protection Warning System (TPWS) with LSE and OBE provides both in cab signalling and protection against SPADs. TPWS protects trains not only from SPADs, but also from overspeeding, rollways, reversing, standstill etc.

5 Indian Train Control System

Chinese Railways has realised that they are a decade behind European Railways in development of railways. They sent a dedicated team to Europe to study various rail technologies and specifications. The team have developed Train Control System specifications based on ETCS called Chinese Train Control System (CTCS) to suit their native existing signalling infrastructure. CTCS has six Application Levels - 0, 1, 2, 3, 3D, 4 and 5.

- Level 0 - Track Circuits, Lineside Signals (Primary)/Cab Signalling (Secondary), for sections with train speeds ≤ 120 kmph
- Level 1 - Block Track Circuits, Cab Signalling (Primary), Balises, ATP for sections with train speeds between 120-160 kmph
- Level 2 - Digital Track Circuits, Balises, ATP (TVM-300) for sections with train speeds ≥ 160 kmph
- Level 3D - Block Track Circuits, Balises, ATP [ETCS Level-1]
- Level 3 - Balises, GSM-R, ATP, using CTCS-Level 2 as the backup [ETCS Level-2]
- Level 4 - Balises, GSM-R, ATP [Moving block]

Levels 2, 3, and 4 are compatible with lower levels. Indian Railways has no specifications for Train Control Systems of their own. It has a choice either to adopt ETCS or to develop Specifications of their own with Indian Industry.

6 CBTC for Mainline

Interoperability is the strongest point of ETCS. It is not available for CBTC systems. Indian Railways does not have interoperability issues unlike European Railways. Flexibility of ETCS allows for a smoother migration from conventional systems without disrupting the operational services than that of CBTC. Automatic Train Operation (ATO) is available in CBTC systems. It is still in development for ETCS. Moving block principle is available in CBTC systems which allows for shorter headways and, consequently, increasing the capacity. It is still in development for ETCS (Application Level 3).

7 Convergence Issue

Each network has specific operational requirements, different infrastructures and may use different communication technologies. The system being developed must be flexible enough to support these differences without compromising the features already achieved by each of the individual systems (ETCS & CBTC)

![ATS Pyramid](image)

![CBTC & ERTMS Components](image)
In the future everything will converge towards the standardization of the operational requirements for train control systems. However, this goal will be difficult to achieve due to the big number of stakeholders involved. Some attempts at requirements standardization are already being pursued, like the EURO Interlocking initiative from the International Union of Railways (UIC). Ensuring the train integrity is one of the challenges facing effective usage of ERTMS Level 3. This is mandatory for the system being able to support moving block operations, while being able to reach the headways already available in CBTC systems.

8 Conclusion

Need of the hour for Indian Railways is to have a firm road map for achieving goals of safe and higher speeds. Indian Railways has to decide whether to go for its own Train Control System specifications suiting native conditions and existing signalling or to adopt globally acceptable ETCS or to adopt well-proven CBTC for mainline.

The information / views expressed in this paper is of the authors and are based on their experience. Comments / observations may be sent to the author at pvr.iriset@gmail.com.

P Venkata Ramana, Senior Professor Signal at IRISET, has graduated from NITW in ECE. He served as Computer Systems Engineer in EIL, New Delhi before joining Indian Railways as IRSSE 1985 batch Officer. He is having 30 years experience in Signalling. He executed several projects in SCR and ECoR involving EI systems including CTC over Networked Els. He served Atkins Rail as Designer for UK Railways. He published papers-EI, CTC, Heavy Haul, Lightning Protection etc., He conducted several Seminars and Symposiums for Commissioners of Railway Safety and S&T Officers. He is Certified Internal Auditor, Workplace Assessor & Java Programmer. He is recipient of Principals Medal of NAIR, GM Award for Development of MIS for Top Management; CSTE and GM Awards for Best maintained Division. This paper is presented in Symposium on Advanced Train Control and Safety Systems for Indian Railways (ATCSSIR) at Indian Institute of Technology, Kharagpur on May 26-27, 2017.