ETCS - LEVEL 1 BASED TRAIN PROTECTION WARNING SYSTEM (TPWS) FOR INDIAN RAILWAYS

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SUMMARY

This paper aims to explain about the ETCS - Level 1 based Train Protection Warning System being implemented in Indian Railways. Indian Railways, one of the largest rail networks in the world, have opted for this solution to provide an enhanced safety to its existing signalling system with the modern techniques for its passenger and freight train operations.

TPWS is the first project in India involving the new generation of train control and signalling, ERTMS. It is based on ETCS Level 1 spot transmission system with continuous supervision to protect against overrun of danger points. The trackside equipment is implemented as an overlay to the existing multi aspect colour light signalling and while drivers follows the line side signals as per prevalent operating rules, the on board equipment provides signalling information inside the cabin and supervises the movement and speed of the train.

The introduction of such a technology is a major step for Indian Railways in its aim to renew its existing railways with signalling systems offering better safety and optimal line capacity use. This project plants the seeds for the development of many more similar projects in India.

INTRODUCTION

ETCS concept based TPWS has been adopted by Indian Railways keeping in view that it is based on a common specification which allows for multiple vendors. Ansaldo STS was awarded to implement this system for two pilot projects:

1. In the Southern Region between Madras Beach/Madras Central and Gummudipundi, section for 50 Kilometers.
2. In the Northern region between New Delhi and Agra Cant, section for 168 Kilometers.

Figure 1: TPWS Test Line Location

30 locomotives, declined in 8 different configurations, and 80 Electro Motive Units are to be equipped with the on-board system.

The specifications for the trackside and on board equipments come from ETCS documents complemented with specific requirements to fit the precise needs of Indian Railways.

This paper will first present the entities involved in the project and give an overview of ERTMS/ETCS. Second it will detail how the overall system is implemented and finally focus on the on board unit main functionalities.

NOTATION

BTM - Balise Transmission Module
DMI - Driver Machine Interface
ERTMS - European Rail Traffic Management System
ETCS - European Train Control System
EVC - European Vital Computer
LEU - Lineside Electronic Unit
MA - Movement Authority
TPWS - Train Protection Warning System
TIU - Train Interface Unit

1 PROJECT ENVIRONMENT

1.1 Indian Railways and Network

Indian Railways is the Department of the Government of India, under the Ministry of Railways, which operates the entire Indian rail network.

The railways span 63,100 Kilometers and cover all the country. The Indian network is the second largest railway in the world under a single
management. It carries approximately 14 million passengers and 1.5 million tonnes of freight daily.

1.2 Ansaldo STS

Ansaldo STS is an international leading technology company operating in the global Railway & Mass Transit Transportation business with the provision of traffic management, planning, train control and signalling systems and services. Ansaldo STS has applied its signalling systems to over 50 % of all High Speed lines worldwide and supplies systems for new ERTMS type lines built in Europe, China, Korea and India.

TPWS project involves 4 entities of Ansaldo STS sharing their knowledge: Italian and French providing trackside and on board equipments, Indian in charge of system integration and installation and Australian to smooth the process between the different teams.

2 OVERVIEW OF ERTMS/ETCS

2.1 ERTMS: the New Signalling Generation

The European Rail Traffic Management System (ERTMS) is a response to the need of interoperability of the railways crossing over Europe. Nowadays over 20 different Automatic Train Protection systems exist in Europe. Thus a train crossing different countries has to be equipped with several train protection systems which is indeed costly and can be time consuming at the borders where the train has to switch from one system to another.

ERTMS consists of two components:

- The European Train Control System (ETCS): an Automatic Train Protection system synthetising the European knowledge in railways to improve safety and optimise traffic supervision
- The GSM-R: a radio system based on GSM standard and used to convey information between the track and the train

The ERTMS, which was initially designed to be a signalling standard in Europe, has crossed the frontiers and is slowly becoming the world standard for train control.

2.2 ETCS Fundamentals

2.2.1 Levels of operation

ETCS can be configured to operate in five different levels of application. The level of application depends on the trackside equipment:

- Level 0: lines not equipped with ETCS where the train is supervised against a defined ceiling speed and where the driver follows the lineside signals
- Level STM (Specific Transmission Module): lines equipped with a national train control system where the ETCS system leaves control over to the national system
- Level 1: a spot transmission based train control system to be used as an overlay on an underlying signalling system
- Level 2: a radio based train control system which provides a continuous supervision of the train by the trackside
- Level 3: a radio based train control system where the train position and integrity is ensured by the train itself. This solution can allow a drastic reduction of the trackside equipment such as track circuits or axle counters.

2.2.2 Performances

Lines operating in ETCS - level 1 permit speed limits up to 250 km/h with 5 minutes 30 seconds interval between trains (Spain).

Lines operating in ETCS - level 2 permit speed limits up to 320 km/h with 2 minutes 30 seconds interval between trains (France).

2.2.3 Modes of operation

Among levels, the on-board equipment is also able to operate in different modes of functioning. Each mode corresponds to a specific situation, with different requirements and interactions with the driver. Among the 16 possible modes are:

- Stand By: This mode is the default mode after the equipment is powered on. In this mode, the driver performs a Start of Mission where he enters his identity, the train configuration and chooses the ETCS level to start.
- Full Supervision: This mode is entered when the on-board unit has received all the track information (distance permitted to run, speed limits, track gradient...) and is able to completely supervise the train.
- Staff Responsible: This mode allows the driver to move the train under his own responsibility with only a ceiling speed control. This mode is used when the on-board unit does not have all the information to fully supervise the train.

- On Sight: This mode enables the train to enter into a track section that could be already occupied by another train.
- Trip: This mode is entered if the train overpasses the permitted distance to run. In this mode, the brakes are applied until the train comes to standstill.
- Sleeping: This mode is a slave mode (the cabin on the other side of the train is leading).
- Shunting: This mode permits shunting movements of the train within a ceiling speed and specified limits.
2.2.4 ETCS language

The ETCS language is used to transmit information between the trackside and the on-board equipment. It consists of a set of predefined variables forming packets embedded in a beacon telegram or a radio message.

A beacon telegram, transmitted through a safety protocol, contains a header providing the beacon identity and several possible packets. Each packet is predefined; it is identified with a number and corresponds to a specific piece of information.

Below is the list of the main packets:

<table>
<thead>
<tr>
<th>Packet number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Linking: provides the list of beacons the train will meet</td>
</tr>
<tr>
<td>12</td>
<td>Movement authority information: permits the on-board unit to determine the permitted distance to run.</td>
</tr>
<tr>
<td>21</td>
<td>Gradient profile: gives the track gradient profile</td>
</tr>
<tr>
<td>27</td>
<td>Static Speed Profile: gives the permitted speed to follow</td>
</tr>
<tr>
<td>41</td>
<td>Level transition: indicates a place where the train has to operate a change of the ETCS level</td>
</tr>
<tr>
<td>65</td>
<td>Temporary Speed Restriction: defines the area of a speed limitation</td>
</tr>
<tr>
<td>68</td>
<td>Track conditions: indicates the place of a track condition (for example, neutral section)</td>
</tr>
<tr>
<td>255</td>
<td>End of information: Indicates the end of the telegram</td>
</tr>
</tbody>
</table>

Table 1: Selection of ETCS packets

3 TPWS SYSTEM DESCRIPTION

3.1 Overview

The Train Protection Warning System (TPWS) is implemented to enhance safe train operations in South and North zones of Indian Railways. It is an ETCS level 1 based Automatic Train Protection system with an entry on both sides of the line realized with the on board operating in level 0 (unfitted area).

The level 1 information is an overlay of the existing multi aspect colour light signalling and thus conveys the same information as the sideline signals. It adds a step of comfort for the driver who is able to monitor a calculated permitted speed inside the cabin and a step of safety as the on board equipment will automatically apply the train brakes if the driver does not respect the speed restrictions or if the train is not stopping before a danger point.

3.2 Level 1 Trackside Equipment

The TPWS level 1 trackside equipment is composed of Lineside Electronic Units (LEU) and Eurobalises (beacons).

The LEU is the equipment that is connected with the external trackside system (interlocking for example). Based on the inputs it receives, the LEU determines which telegrams shall be sent to the train through the Eurobalises at the signalling information points.

![Figure 2: TPWS Information Point](image-url)

The information points are composed by the Eurobalises and constitute the spot transmission system between the track and the train. When the antenna of the train passes over the Eurobalise, it is awoken and it transmits its information through electromagnetic radiation.

The Eurobalises are organized in balise groups, each balise transmitting a telegram and the combination of all telegrams defining the message sent to the train. A balise group consists of between one and eight Eurobalises. The number depends on the amount of information to be transmitted to the train.

A Eurobalise can be either "fixed" (not connected to the LEU and the programmed telegram of the balise is always the same) or "switchable" (interfaced with the LEU and the balise telegram depends on the signalling).

3.3 Information Points

In ETCS level 1, information points must be installed before each sideline signal (for both directions). They transmit information corresponding to the aspect of the signal (green, yellow or red, with or without a 'A' mark).

If the signal is green, the balises transmit an update of the permitted distance to run along with the corresponding track description (speed, gradient profile and linking...). The updated permitted distance to run (Movement Authority) is given for a least until the next lineside signal and in nominal conditions for 2 track sections.

If the signal is red, the balises transmit information to stop the train. Therefore, in order not to have the on board unit stopping the train, the driver has...
to observe the lineside signal to know when to proceed and read the balises in front of the signal. As level 1 is an intermittent transmission system, additional information points may be needed at places other than main signal to improve safety and performance. It is the infill information. The infill balises provide the same information as the balises at the signal and so when the signal is green, the update of the Movement Authority is known in advance and the train does not have to slow down at the signal. Other information points can be placed anywhere on the track when needed to indicate for example temporary speed restriction, neutral sections or even the station names on the driver display inside the cabin.

3.4 Functional Principles

Figure 3 represents a situation that can happen on TPWS trackside. The train is arriving at full speed toward a red signal. The four balise groups (BG) provide the same information as the lineside signals. If the signal is green, the Movement Authority is given for two sections. If the signal is yellow, it is given for one section and if red, stop is mandatory.

![Figure 3: Interaction between Track and Train](image)

The on board unit processes the balise groups transmission and displays in the cabin the same information as on the trackside. When all signals are green, the driver is given to follow a constant permitted speed. When approaching a red signal, the on board unit will guide the driver to the stop location. The on board will also control that the driver behaves correctly and will apply the brakes if required.

When passing over BG1, the on board unit has a permitted distance to run long enough to stay at full speed. The driver sees on the display inside the cabin the permitted speed to follow and the speed of the train. When passing over BG2, the Movement Authority is updated for one section so the driver does not have any perturbation.

When passing over BG3, the permitted distance to run remains the same. When the train approaches the stop location, an audible warning is given to the driver and the remaining permitted distance to run is displayed to him. Then the train enters the braking curve, the permitted speed decreases slowly to come to zero at the stop location.

4 TPWS ON BOARD UNIT

4.1 Train Configurations

TPWS on board unit has a clear and identified interface with the train. The connection with the train inputs/outputs (brakes, wheel sensors) is simple to realize. The system can be put into operation in a train in a short time without difficulties.

The on board unit is designed to handle different train configurations. On the southern line, the trains are driven by Electro Motive Units. One TPWS on board unit manages only one cabin. On the northern line, the trains are hauled by locomotives. One TPWS on board unit manages the two cabins at both ends of the locomotive.

For both lines, the on board unit can function in a single or multiple unit configurations and can be composed of up to 24 coaches.

The maximum speed of the train is between 80 and 130 km/h depending on the configuration of the train.

The configuration can be selected by means of a hardware switch during the Start of Mission procedure after the power up of the on-board unit.

![Figure 4: TPWS On Board Unit](image)

4.2 Safe Calculations

Below the functional requirements, the TPWS on board equipment allows for safe calculation and availability.

All the information going through the on board unit is encoded with a safety code and all the hardware components of the system are doubled. This permits to compare the output of two similar components and thus verify they give the same result.
4.3 On Board System

The core of the on board unit is called the European Vital Computer (EVC). It is the safe calculator that handles all the functional management of ETCS and commands the outputs of the train. It processes the ETCS messages sent by the trackside and according to the position and speed of the train, it monitors the movement of the train and applies brakes when needed. It also displays all the necessary information to the driver.

The EVC is connected to the inputs/outputs of the train through the train interface unit (TIU). It communicates with the driver through the Driver Machine Interface (DMI).

The reception of the ETCS information is fulfilled by the Balise Transmission Module (BTM). It decodes the electromagnetic field sent by the Eurobalise.

The odometer evaluates the position, the speed and the direction of the train according to the wheel sensors information. The position and the speed come with a confidence interval in order to ensure safety.

To facilitate the maintenance of the on board unit, a memory providing information about the missions and storing the faults is accessible offline. The parameters of the on board unit can also be updated offline by the maintenance staff.

4.4 Driver Machine Interface

The DMI is the screen inside the cabin on which the driver visualizes the necessary information. The DMI function is mainly to show the current speed of the train and the permitted speed to follow but it also displays the operational ETCS level/mode of the train and conveys the driver interactions with the on board unit.

The DMI is able to generate sounds which permit to retain the attention of the driver when necessary (for example when the current speed of the train exceeds the permitted speed).

Two types of DMI's are used in TPWS. One is the CENELEC standard type and the other is the Simplified DMI specifically designed for the Indian Railway environment for Level 1 operation.

4.5 Braking Curves

The on board unit commands two different brakes: the service brake and the emergency brake. For the comfort of the passengers, the service brake is used as a first line of intervention. If the service brake is not sufficient, then the emergency brake is triggered.

The decision to trigger the brakes is guided by the braking curve calculation on board the train.

4.5.1 Ceiling speed monitoring

In modes where ceiling speed monitoring is performed or when the distance permitted to run is long enough, the permitted speed is constant and corresponds to the most restrictive speed limit given by the trackside (or even the maximum speed of the train parametered). The on board unit triggers the service brake if the train speed exceeds the permitted speed by 5 km/h. The service brake is released when the train speed comes back below the permitted speed. The emergency brake is triggered when the train speed is 10 km/h higher than the permitted one and is released only at standstill.

4.5.2 Target speed monitoring

In modes where the on board unit supervises a permitted distance to run (Movement Authority), it computes the braking curves. The movement authority is composed of two points: the End Of
Authority that is the point to which train is authorized to move and the Danger Point that is the point to protect.

The braking curve calculation for the emergency brake intervention guarantees to protect the danger point by considering the train characteristics. The calculation takes into account:

- the guaranteed braking capacity of the train for an emergency brake
- the traction model which describes the time between ordering traction cut off and the actual cut off of the traction
- the emergency brake model which describes the time between ordering brake application and reaching full brake effort
- the acceleration due to the gradient profile

The braking curve calculation for the service brake is used as a first line of intervention. As in ceiling speed monitoring, the service brake is released when the train speed comes back below the permitted speed.

The permitted speed shown to the driver guides him to come to standstill at the End Of Authority. If the driver crosses the End Of Authority, the emergency brake is applied.

**CONCLUSION**

TPWS trackside and on board units are currently operational on the Southern line between Madras and Gummidipundi. The system was inaugurated on the 2nd of May 2008 by the Indian Union Minister of State for Railways.

By providing signalling information inside the cabin and supervising the train movement and speed, TPWS system provides a better safety on the line. It also enhances the trains' punctuality by avoiding accidents. Another advantage of TPWS is that it supports mixed trains circulation. Trains with and without TPWS equipment can run on the same line without disrupting the traffic.

The ETCS level 1 TPWS system is a wise move to plan signaling improvement on an existing network. This allows a smooth migration from areas not equipped with any signaling system or equipped with proprietary system to a worldwide standard. The chance of ERTMS is to offer a standard platform for any operator in the world.

Besides TPWS, ERTMS/ETCS is a traffic management system that offers a complete set of features to meet the different possible requirements of a signaling system. The TPWS on board unit was designed for ETCS level 1 but it could easily evolve to support ETCS level 2 features. The architecture, both software and hardware, would remain almost the same. It would mainly require adding a radio interface.