TRAIN CONTROL SYSTEMS FROM ANSALDO STS - ERTMS/COMMUNICATION BASED SIGNALLING

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SUMMARY

There is a range of operational and functional requirement starting from conventional main line, high speed lines to mass transit applications – conventional to driverless operations. This paper highlights the train control systems designed, developed and applied by Ansaldo STS for the above applications.

Abbreviations
ATP: Automatic Train Protection  
ATO: Automatic Train Operation  
CBAS: Communication Based Authority System  
CBI: Computer based Interlocking  
CBTC: Communication Based Train Control System  
CTCS: Chinese Train Control System  
CTC: Centralized Traffic Control  
DED: Dragging Equipment Detector  
DTO: Driverless Train Operation  
ERTMS: European Rail Traffic Management System  
ETCS: European Train Control System  
EVC: European Vital Computer  
GPS: Global Positioning System  
GSM-R: Global System for Mobile-Railway  
HBD: Hot Box Detector  
HSL: High Speed Line  
IEEE: Institute of Electrical and Electronics Engineers  
IXL: Interlocking  
MA: Movement Authority  
MAL: Movement Authority Limit  
O&M: Opération & Maintenance  
PTC: Positive Train Control  
RAMS: Reliability, Availability, Maintainability & Safety  
STO: Semi-Automatic Train Operation  
TPWS: Train Protection & Warning System  
UTO: Unattended Train Operation

1. INTRODUCTION

During the last few decades there has been a growing demand for higher capacity, interoperable, multivendor train control and signalling while maintaining and increasing the safety integrity of these systems. The paper covers ERTMS, its applications by ASTS and Communication Based signalling both for main lines (both for low/medium and High density lines) as well as mass transit.

1.1 ERTMS

Since 1992, the European Commission has supported and coordinated research and development activities for the ERTMS project, the European Rail Traffic Management System.

ERTMS allows for thorough interoperability in the European Railway network by means of reducing the investment and maintenance costs incurred by the signalling companies involved. ERTMS systems have now spread outside Europe to China, India, Australia, Saudi Arabia, and South Korea.

1.2 Communication based signalling CBTC for mass transit

Communications based train control (CBTC) is the radio based train control architecture for mass transit. It is a continuous and automatic train control system carried out adopting modular and interchangeable architecture both for train-borne and wayside subsystems.

In recent years there has been a significant expansion in the development of standards for CBTC by international organisations and consortia.
The most important developing standards for the market are:

- Institute of Electrical and Electronics Engineers (IEEE) in North America-IEEE1474.
- ModUrban Consortium in Europe.

1.3 Communication based signalling – for main line

Communication based signalling as applied for freight railway is defined generically by PTC in the USA or Communication Based Authority System (CBAS) in South Africa.

PTC is defined by any system that is capable of preventing:
- Train to train collision
- Over-speed derailments
- Incursions into work zones
- Movement through a switch in wrong position.

CBA Systems provide all the capabilities of a PTC system besides advanced traffic management functions.

2. ERTMS APPLICATIONS FROM ANSALDO STS

Ansaldo STS has been actively involved in the ERTMS segment in Europe, India, Korea, and Libya.

The ERTMS applications delivered by Ansaldo STS include ERTMS level 2 based high speed lines with no optical signals, to applications which have been interfaced with existing ATP systems in operation, to applications involving national functions as in CTCS in China and TPWS in India.

A map of ERTMS applications from Ansaldo STS is shown in Figure 1.

Figure 1: Ansaldo STS - ERTMS applications

2.1 High speed line applications in Italy

High speed line (HSL) applications in Italy feature:
- ERTMS/ETCS level 2
- No light signals - Fixed signals along the line and in the stations
- No other backup signalling systems
- 300 km/h max speed
- Headway
  - 2.5 min theoretic
  - 5 min for operation.

The architecture applied by Ansaldo STS in HSL in Milano Bologna was based on a single centralised CBI whereas the application in Torino Novara is based on distributed CBI.

Figure 2: HSL Milano -Bologna Architecture

2.2 Other ERTMS on board applications for HSL

Ansaldo STS has been involved in the HSL application where the EVC has been interfaced with existing systems as follows:
At first, controls the standards:
- TVM
- ERTMS level 0, level 1, level 2
Meets with other standards requirements by adding:
- Pseudo STM (KVBr, LZB/PZB, ZUB)
- STM according to the standard FFFIS STM

Provides MMI interface for LZB/PZB, TBL, TBL2 and ATB. The EVC structure and its interfaces are shown in Figure 3.

**Figure 3: EVC applications**

**2.3 ERTMS application in India**

Ansaldo STS has implemented ERTMS applications in India in two pilot projects:
- TPWS South: 52 km, 150 signals, 84 coaches
- TPWS North: 192 km, 580 signals, 35 coaches.

Figure 4 (below) shows the system architecture for TPWS in India.

**3. COMMUNICATION BASED SIGNALLING**

Ansaldo STS has been involved in Communication Based Signaling system for both Mass Transit as well as Main Line. Communication based signaling is increasingly being required in order to achieve lower O&M expenditure due to minimal reliance on trackside and other field infrastructure.

**3.1 CBTC for Mass Transit**

CBTC is the radio based train control architecture for Mass Transit. It is a continuous and automatic train control system carried out adopting modular and interchangeable architecture both for trainborne and wayside subsystems.

CBTC, thanks to the high-capacity, bidirectional radio train-to-wayside data communications is able to implement advanced Automatic Train Protection (ATP) functions as well as Automatic Train Operation (ATO), achieving high-resolution train location determination and allowing very high performance virtual block functions.

CBTC meets all customer needs:
- Revamping of existing lines to minimise both costs and operation disturbances during the cutover; e.g. “OURAGAN project” for Paris line 3.
- Deployed for new lines e.g. Shenyang Metro in China
- Overlay and new implementation in Ankara
- UTO in Taipei(Driverless)

Main features of CBTC:
- Very high Train and Passenger Safety Protection
- Centralize Operation for optimum regulation.
- Optimize Traffic Performances (running speed and headway).
- Allows smooth upgrade for existing line.
- Manage CBTC Train and No CBTC Train.
- Could be implemented on Existing Signaling System.
- Flexible from simple ATP up to Driverless solution.
- Reduce number of wayside equipments.
- Reduce implementation and maintenance costs.
- Off the shelf radio system (802.11 standard).
- Fall back operation with intermittent ATP (IATPM)
3.1.1 CBTC Architecture from Ansaldo STS

The architecture implemented by Ansaldo STS to meet the above features and requirements complying with IEEE1474 can be either centralised or distributed meeting all the required RAMS targets for SIL4.

![Figure 5: CBTC Architecture from Ansaldo STS](image)

3.1.2 CBTC fundamental concepts

- Vehicle-Centric Profile Train Control
- Trains know their location vitally with a high degree of accuracy
- Safe train separation and movement controlled by movement authorities (MAL) based on Virtual fixed block or Moving Block.
- Continuous, high speed, two-way communications between wayside and vehicle

3.1.3 CBTC principle

Traditional signalling systems are based on so called fixed blocks: the railway is divided into sections of track, which are separated by signals.

A train is not allowed to enter a given track section (=block) before the preceding train has cleared it. This system has a number of disadvantages, one being its lack of flexibility: the block size is the same for all trains regardless of their speed and braking performance. Thus the large safety distances required by fast trains are imposed on slower trains as well.

This is illustrated in Figure 6 below.

![Figure 6: Conventional Fixed Block System & Moving Block System](image)

A moving block/virtual Block system does not require traditional fixed-block track circuits for determining train position. Instead, it relies on continuous two-way communication between each controlled train and a wayside control centre.

On a moving block/virtual Block equipped railway each train transmits its identity, location, direction and speed to the area computer (Zone Controller) which makes the necessary calculations for safe train separation and transmits this to the following train.

The radio link between each train and the area computer is continuous so the computer knows the location of all the trains in its area all the time.

The Zone Controller will calculate the train position under the worst case scenario according to the reported train position and the uncertain tolerance. Then, the Zone Controller will regard the train as an obstruction to the following train and calculate MAL (Moving Authority Limit) for the following train which is close to the preceding train as possible.

![Figure 7: Moving Block/Virtual Block System](image)

A CBTC system using virtual blocks and ATO doesn’t required theoretically track circuits and signals (neither train driver on board). A fall back system is, however, more desirable and, often, required by the customer in order to manage the line with mixed mode or mute trains (not communicating trains or with DCS in failure).

3.1.4 CBTC modes of operation

CBTC can be applied with the following modes of operation:

- Conventional Semi-Automatic Train Operation (STO) - onboard ATP and ATO, with semi-automatic driving, limited action required by driver (open/close doors).
- Driverless Train Operation (DTO) - Fully automatic, attendant provides customer care and failure management
- Unattended Train Operation (UTO) - Fully automatic, no onboard staff at all, optional roving attendants
3.2 Communication based signaling for main line

The generic requirements that are requested from customers for main line are the following:
- a system which has minimal reliance on trackside and other field based infrastructure;
- Reduction in Staff in Stations
- Centralized Safe working system with central post performing the IXL, MA & CTC functions.
- No train detection systems in the line.
- Limited Radio coverage
- Communication between the central post & field devices by radio or by cable, if present.
- Use of radio system other than GSM-R.
- Interoperability between Low/Medium density lines and high density lines
- Fall-back by Rules and Regulations
- Reduction in O&M costs
- a system which uses open systems architecture to provide for flexible alternatives for the sourcing of components and systems.

3.2.1 Generic Solution from Ansaldo STS for communication based signaling system

There has been increasing need for an integrated solution for heavy haul freight railway and mixed passenger/freight railway.

The main functional requirements for such systems are:
- Train Supervision system providing the network controller to
  - Setting routes, points,
  - Train tracking,
  - Monitoring system status,
  - Viewing Train Movement Orders,
  - CCTV images from level crossings, On board in case of a driverless operation.
- Diagnostic & Maintenance
- SCADA/Asset Protection
- Automatic Train Protection for speed and limit of authority enforcement.
- Mobile possession terminal for work zone protection and Hirail.
- Asset Protection devices like HBD, DED etc.
- Automatic Train Operation, if needed.
- Driverless Operation for some dedicated heavy haul railway.
- GPS based location system in order to minimize the number of field devices like balises etc.

Ansaldo STS has been associated with GPS based location system as in Alaska Collision avoidance system (PTC application in USA), GRAIL – European project for developing GNSS based Location determination system for enhanced odometry, use of virtual balise instead of physical balise in ERTMS and its application on other communication based signalling systems.

3.3 Communication based signalling architecture for main line

![Communication based signalling system architecture](image)

Figure 8: Communication based signalling system architecture

4 Conclusions
Ansaldo STS has so far developed and applied a range of train control systems ranging from high speed lines, conventional main lines, heavy haul, mass transit – conventional and driverless, light rail.
This paper has brought out ASTS solutions not only for High speed line, Passenger lines, Mass transit but also the application of proven Generic solutions and proven certified products for application to medium density lines.