Technological systems for High Speed lines, ERTMS, security, power systems

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Technological systems for High Speed lines

- Signalling
- Power supply
- Safety and security
Signalling Systems

• High speed signalling systems in EUROPE

• The ERTMS: European Rail Traffic Management System
  • ERTMS benefits related to the system (Why ERTMS?)

• Main features of ERTMS (Which ERTMS?)
High speed signalling systems in EUROPE

- TVM
- LZB
- LZB+ASFA
- EBICAB
- ERTMS L1/L2+ASFA
- BACC
- ERTMS L2

High speed signalling systems in EUROPE
The German signalling system for HS lines LZB (LinienZugBeeinflussung)

- Vital, computerized, continuous and centralized ATC (Automatic Train Control) system for speed up to 187.5 mph;
- A single centre manages about 62 miles of double track section line;
- The system is overlapped to the national light signalling system;
- The safe bidirectional link train/centre realized with a cable loop laid into the track for all the line length;
The German signalling system for HS lines LZB (LinienZugBeeinflussung)

- Each centre permanently connected to all interlockings and trains of its area as well as to adjacent centers for in and out relationships;
- The trackside vital computer sends cyclically, to every on board computer, data concerning the length of the available braking distance and the localization of braking initiation in respect of the braking train capacity.
The Spanish signalling systems for HS lines

- **Speed up to 187.5 mph**
  
  German LZB overlapped to the national light signalling system ASFA (Anuncio de Señales y Frenado Automatico). The latter is a system for on board repetition of trackside light signals used by conventional trains running the HS lines;

  **OR**

  ERTMS (European Rail Traffic Management System) level 1 and 2, overlapped to the national light signalling system ASFA.

- **Speed up to 137.5 mph**
  
  EBICAB (Électrique Bureau CABine) is a semi-continuous system based on wayside transponders which transmit to trains information for supervision of the braking curve (ATP = Automatic Train Protection).
The French signalling system for HS lines: TVM (Transmission Voie Machine)

- Vital ATP (Automatic Train Protection) system with distribute architecture for speed up to 200 mph;
- Single Trackside Control Centers (TCC) located every about 9 miles;
- The system operates without trackside signalling;
- Continuous track-to-train transmission through track circuits.
The French signalling system for HS lines: TVM (Transmission Voie Machine)

- Continuous speed control, calculated on board for each block section and based on data received from trackside (section length, speeds at the beginning and at the end of the block section, slope);
- Audio Frequency Track Circuits:
- Other auxiliary transmission media (balises) needed to manage track conditions (Power supply, Tunnels, etc.).

On line Paris-Strasburg ERTMS L2 system has been implemented together with TVM national system.
The Italian signalling system for HS lines

- **Speed up to 156.0 mph**
  Italian BACC (Blocco Automatico a Correnti Codificate) national light signals block system, based on coded track circuits and on board repetition of trackside light signals. These HS lines are also used by conventional trains (to be soon upgraded to ERTMS);

- **Speed up to 187.5 mph**
  ERTMS (European Rail Traffic Management System) level 2. In the Italian application ERTMS operates without overlapping on other systems and without trackside signals.
  Only ERTMS equipped trains can run on such HS lines. The lack of a back-up system (ERTMS level 1 or similar) is balanced by a very high level of redundancy of subsystems involved.
Why ERTMS?

1. **Interoperability**: European Commission supports the development of operational and technical interoperability with unified signalling equipment in order to open railway markets to all train operators;

2. **Safety**: ERTMS equipments are designed and produced in compliance with CENELEC standards;

3. **Performance**: high speed can be reached using the lowest amount of time distance between the trains (in Italy only 2’30” between two trains running at 187.5 mph);

4. **Availability/Reliability**: due to the particular ERTMS architecture, there are less equipments along the lines, reducing fault probability and improving system reliability.
ERTMS levels

- ERTMS Level 1:
  Overlay using Eurobalises and track side signals;
- ERTMS Level 2:
  Fixed Block Authority is communicated directly from the Radio Block Center (RBC) to the train using GSM-R. Wayside track signals are optionally required;
- ERTMS Level 3:
  Introduction of “moving block”. Wayside track signals are not required.
Which ERTMS? ERTMS level 1

- Discontinuous system working on an underlying and already existing signalling system; provides a continuous speed supervision;
- Movement authorities and track description data are generated by electronic Lineside Equipment Unit (LEU), located by side of the tracks, on the basis of information received from external signalling systems and track circuits;
Which ERTMS? ERTMS level 1

- Movement authorities are transmitted to the train via wayside equipments called balises;
- The on-board sub-system calculates a dynamic speed profile taking into account the train braking characteristics and commands the brake application if necessary;
- Lineside signals are required. Loop (cable or radio) could be used in order to immediately refresh information related to the clear signal aspect (infill function).
Which ERTMS? ERTMS level 2

• Radio based Automatic Train Control (ATC) system (working on optional signalling system), which provides a continuous speed supervision toward fixed points of the line (end of block sections, speed restrictions, etc.);

• Movement Authorities, track description data, temporary speed restrictions and emergency messages are generated by Radio Block Centre (RBC) on the basis of information received from train itself, external interlocking system and track circuit. A RBC usually manages about 62 miles of double track section line.
Which ERTMS? ERTMS level 2

- Messages are transmitted/received to/from the train via GSMR system;
- Balises are used mainly for spot transmission of train location reference, to manage hand-over between RBCs and other particular situations;
- The on-board sub-system calculates a dynamic speed profile taking into account the train braking characteristics and commands the brake application if necessary;
- Lineside signals are optional.
Example of trains movement management with ERTMS Lev.2
GSM-R System: coverage redundancy

- High level of signal coverage
- In case of Fault or Outage of one BTS the adjacent BTS provide ERTMS Radio Coverage and GSM-R Traffic Channel
Which ERTMS? ERTMS level 3

- Main features similar to ERTMS level 2, except for:
  - Functional difference: the target is the end of the preceding train (moving block);
  - Technical differences:
    - On-board equipment to check the train integrity is required (RBC needs this information to calculate movement authority);
    - Track Circuit for train detection are not required.

- Performances:
  - Increase line capacity (relevant for lines with intense traffic at low speed as subway)
Italian HSL System Architecture
ERTMS On Board MMI

The on board computer calculates the maximum permissible speed, monitors the real speed and controls the driver’s indicators.

Over speed detected by the system
Railway Power Supply
RAILWAY POWER SUPPLY

- Electrification systems in Europe
- Electrification design criteria – Standard of Interoperability
- Italian High Speed line example
- Power supply for signalling
Railway power supply: an integrated system to feed the train

HV POWER LINES -> SUBSTATIONS -> CONTACT LINE -> TRAIN

REMOTE COMMAND AND CONTROL SYSTEM TO GUARANTEE A GOOD OPERATION
Main advantages: electrical versus diesel traction

- greater power/locomotive weight ratio;
- less pollution; electricity may be obtained from renewable sources;
- lower locomotive maintenance, personnel and energy costs;
- greater acceleration and therefore faster commercial speed with the same maximum speed.
European electrification systems for traditional lines

- 750 V d.c.
- 1.500 V d.c.
- 3.000 V d.c.
- 15 kV 16.7 Hz
- 25 kV 50 Hz
- Not electrified
European electrification systems for high speed lines

- 25kV ac 50 Hz started in France and developed in Belgium, Spain and Italy supplied directly from the high voltage national provider network at industrial loads frequency;

- 15kV 16 2/3 Hz developed in Germany and supplied from dedicated high voltage network at “railway frequency”

Both of these systems are referred to the Technical Specification of Interoperability (TSI) for Energy Systems issued by the European Union
Electrification design criteria

TSI of the energy subsystem defines the main features of the electric traction system in order to be certified as interoperable.

The main aspects to be evaluated in the electrical design should be:

- Quality of the power collection and voltage to the train during operation
- Quality of mechanical interaction between contact line and train pantograph at rated speed
- Reliability, Availability during operation
- Maintainability and management of the electrical installations
Quality of the power collection

The quality of the power collection during operation should be evaluated with the voltage values calculated by integrated simulation programs based on the train circulation.

Power absorbed by Train

Voltage Calculation

\[ U_{\text{mean useful}} = \frac{\sum_{i=1}^{n} U_{p_i} \times |p_i| \times dt}{\sum_{i=1}^{n} T_i} \]

Voltage Limits

<table>
<thead>
<tr>
<th>Power supply system</th>
<th>HS TSI lines</th>
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<tbody>
<tr>
<td>a.c. 25 000 V 50 Hz</td>
<td>Zone and Train</td>
</tr>
<tr>
<td>a.c. 15 000 V 16.7 Hz</td>
<td>22 500</td>
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<td>14 200</td>
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Quality of mechanical interaction

The quality of mechanical behaviour of the contact line with the train runs at maximum rated speed should be simulated and measured before operation.
Reliability, Availability during operation

The Reliability and Availability of the system have to guarantee normal operation in case of substation or a part of the supply system fault.

Redundancy of the power supply system architecture in case of one substation out of service.

Redundancy of the substation plant in case one component is out of service.
Maintainability and management of electrical installation

Command and Control of all the electrical installations in the “Remote Control Room” in order to have:

- Control of the electrical system according to the circulation of the trains and reconfiguration in case of fault or maintenance
- Diagnostic data collection to prevent faults in the equipment, the out of service of plants and organize the maintenance interventions
The 2x25 kV Electric Traction System: example of the Italian supply system

Rated railway traffic to be supplied:
- Train Type: ETR500
- Rated Power: 12 MW
- Speed: 187.5 mph (300 km/h)
- Total mass: 771.6 ton (700 t)
- Frequency: 5 min.

Advantages of the 2x25 kV Electrical System:
- Possibility to supply power to high-traffic trains with a great distance between ESS
- Low voltage drops
  - Less number of ESS
  - Less environmental impact
- Smaller inductive effect on the conductors in parallel with the line and on the people
Main Characteristics of the 2x25 kV Italian Power Supply System

Supply system:
✓ Substation with 150/25/-25 kV transformer
  - Average distance 31 mi (50 km)
  - P=2 x 60 MVA
✓ PP with +25/0/-25 kV autotransformers
  - Average distance 7,4 mi (12 km)
  - P=2 x 15 MVA
✓ Contact line:
  - Messanger wire = 0,186 in² (120mm²)
  - Contact wire = 0,232 in² (150mm²)
  - Contact wire height = 17,38 ft (5,3 m)
Power Supply of ERTMS

- Every shelter has a double energy source.
- 1kV lines are supplied by a NO-BREAK source in technological building.
- Electrical system has 3 phase with earthed neutral wire.
- Shelters contains electronic equipment for GSM radio block center.
Safety & Security in High Speed Lines
Safety and Security
Design Process in the high speed railway system

INPUT for design
- Requisites
- Standards
- Criteria
- Objectives

Accidents Databases analysis
- Accidents Databases: hot and cold scenarios
- Risk analysis

Design criteria
- Design Specifications
- Organisational and managerial specifications

Safety / Security assessment
- Compliance with requisites
- Compliance with safety/security objectives
- Safety and Security Dossier
Security targets

Integrated system of measures for surveillance and protection of critical infrastructure such as:

- stations areas,
- platforms,
- public areas,
- tunnels,
- cargo terminals,
- technical installations for electricity, signalling and communications

in order to assist the reduction of opportunity for crime (sabotage, terrorism) and the fear of crime, thus creating a safer and more secure environment.
Security architecture

Wide Area Network

- Security Operations Control Center
- HS train depots
- Electrical Sub-station
- HS Station
- Bridges and tunnels

Intrusion-detection system
Closed-circuit television (CCTV)
Access control system
Examples of security equipments

Closed-circuit television (CCTV)

Intrusion-detection system

Access control system
European Control rooms

- Roma Termini - Italy
- Munich - Germany
- Zaragoza - Spain
- Bologna - Italy
Security - Station

- Indoor CCTV camera
- Outdoor CCTV camera
- Speed dome CCTV camera

Long distance network
Safety targets

Accidents prevention

Facilitating rescue

Mitigation of consequences

Facilitating evacuation
Safety – *tunnels*

- Access: intermediate ways/exits *(Vehicle-accessible windows and by-pass)*
- Access: ways/exits *(portal)*
- Passenger escape routes and rescue team entry points equipped with emergency signs and marking, in-tunnel emergency lighting and electric motive force systems and commode handle
Safety - tunnels

- In-tunnel radio-propagation system for rescue operations
- Emergency telephone system (speakerphone) and public address
- In-tunnel emergency lighting and electric motive force systems
- Water fire-fighting system, overpressure system (filter zone) in intermediate access points to prevent smoke propagation to the escape route
- ERTMS II (European Rail Traffic Management System) signalling system
- Control desk (Centralized system for managing rail traffic and emergency in the tunnels)
Safety - stations

- Smoke-extraction systems (air or water barriers)
- Resistance and reaction to fire of the structures and materials
Safety - stations

- Fire detection and alarm systems
- Access/egress:
  - Emergency access to station and guide way, security fencing, access gates
  - Emergency exits (stairs, doors) and cross passages (vertical/horizontal) with enclosure requirements and fire separations for aerial and tunnel stations
- Fire-extinguishing equipment (fire-fighters, hydrants)
Safety - stations

- Communications devices:
  - Speakers and amplifiers for public address system coverage of all public areas
  - Variable message displays and signage in all public levels of stations

- Fire protection:
  - Fire wall ratings and occupancy separations (set backs, barriers)
  - Low combustibility and optical smoke density materials for stations, tunnels and vehicles

- Visibility:
  - Ability to see into stations from the outside (use of open spaces, glass, and other transparent design elements)
  - Emergency lighting and its duration
Safety – *Rolling Stock*

- Car-to-platform gap
- Emergency braking
- Flame and smoke emission characteristics
- Hazard alarms for the following:
  - No-motion detection system indicates no-motion when the train is moving
  - Door opens spontaneously when not commanded
  - Door opens on wrong side of vehicle
  - Excessive currents or overheated equipment that may cause fire
- Cab equipment:
  - Warning devices, "horn" and "bell"
  - Cab makeup interlocks to establish train line
- Interior/exterior appointments:
  - Emergency lighting
  - Exit path marking lighting
Safety and Security – Emergency Plan

The design of Safety and Security for the High-Speed Railway System is applied:

- to stations (escape of the passengers)
- to tunnels (technologically assisted escape and management of the degraded traffic)
- along the whole railway line (degradation of the traffic)

and it is implemented by the EMERGENCY PLAN which takes into account:
architecture of all the systems, facilities, equipment and managerial aspects of organization in Normal conditions and Emergency.