Command and control for Italian high speed trains

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Abstract

The paper starts with a synthesis of Italian High speed system basic requirements and of its command and control traffic system.

Then it is given a short description over present state of the art of project, with reference to architecture, to technical solutions and to control centre features.

Finally it is given information about compatibility and integration with European Train Control System (ETCS) whose standard is being developed.

1. Introduction

Italian State Railways are going to realise some new High Speed Lines to connect the biggest towns of Country: Milan and Naples, Turin and Venice, Milan and Genoa by means of two new tracks joined to those existing on main lines. They are very important even because they give power and complete railway system to connect each other the nodes at high traffic level as Rome, Bologna and Florence.

In the Milan - Naples route it is settled present line "direttissima"Rome - Florence, that will be adapted in proper way.

All the lines as above-mentioned form an high speed system whose technologies must have got an high homogeneity level to guarantee performances answering to the customers needs.

The command and control structure is the brain of this system. It permits to manage traffic in optimised way with the help of centralisation of the management functions and of the high level of automation of headway installations and peripherical apparatus.
2 Basic specifications for Italian high speed lines

2.1 Main requirements of command and control system
The signalling system for high Speed lines must realise on safety its functions until maximum project speed which is 300 Kilometer per hour. That speed is a project parameter but must not be a technological limit, to permit future developments.

In normal operating, signalling system must permit the transmission by ground to train and the display on board of all the information needful for safe train running. It is necessary to take into account some possible operating break-down of either system parts or a single train.

In case of system break-down, the residual resources or an emergency system must guarantee the management of train movements in all the damaged area.

In case of single train break-down it must be guaranteed the running continuation at least until a proper next service point.

In the overall system project it must take into account the possible future interfaces with European Command and Control system that UIC is developing at present.

It is required an high modularity to permit an eventual change of parts because of some sub-system European standardization.

The system has to be suitable at Automatic train Operation (ATO).

The signalling installations are classified in line installations, signal-boxes and traffic control and regulation center.

The line installations realize functions of block headway and train protection. The block headway system by use of a suitable safety transmission system must communicate on board parameters which exercise influence upon train running:

- fixed data (layout parameters, singular points)
- variable data (speed reduction, passing tracks, previous train position).

To reach this purpose it is necessary to employ continuous and discontinuous communication supports with technological performances proportioned to data volume that has to be transmitted.

Data transmitted must be enough to build on board the safety characteristic curve and speed continuous control.

The theoretical train spacing must be on time lower or equal to 2’30” at speed of 300 Km/h.

Management of line apparatus must be centralized in the service boxes as well as possible.

In the movement, cross-over and junction points signal-boxes must have working and operation similar at Central Electric Push-button Route Apparatus (ACEI), already used by Italian State Railways.

However these installations will be realized by use of computer technology, according to new FS standard.

Service installations of every line must be managed by Centralized traffic control Systems very similar to those previous existing in the Italian Railways. In addition it must be possible the management on safety of some
emergency functions to reduce information and registered order by ground to driver.

2.2 Reliability, Availability and Maintainability of High Speed System

High Speed System needs of a great level of reliability, availability and maintainability of its sub-systems to reduce the frequency of failures which cause either directly or indirectly times more or less extensive of line break-down and/or of great reduction of speed operating, by compromising the operating regularity.

To achieve this purpose, they were identified for the main sub-systems of Hight Speed system the failure rate, MTBF and reliability values, which are shown below on table 1 and were considered as project parameters. These values for the train are just an hypothesis.

The parts of sub-systems which have to be provided of proper redundancy levels (intrinsically doubled, stand-by, stand-alone) were identified throughout the project.

To reach these values of reliability it will be defined on overall plan of reliability and maintainability.

In this one must be defined medium times of active maintenance (MTTR) which must be very short by means of use of modular equipments easily replaceable and standard hardware.

**TABLE 1**

<table>
<thead>
<tr>
<th>Subassembly</th>
<th>Failure rate</th>
<th>MTBF</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch</td>
<td>$2.8 \times 10^{-5}$</td>
<td>$3.5 \times 10^4$</td>
<td>0.98</td>
</tr>
<tr>
<td>Track circuit</td>
<td>$8.3 \times 10^{-6}$</td>
<td>$1.2 \times 10^5$</td>
<td>0.994</td>
</tr>
<tr>
<td>Signal</td>
<td>$2.5 \times 10^{-6}$</td>
<td>$3.9 \times 10^6$</td>
<td>0.998</td>
</tr>
<tr>
<td>Centralized Traffic Control</td>
<td>$2.7 \times 10^{-4}$</td>
<td>$3.7 \times 10^3$</td>
<td>0.823</td>
</tr>
<tr>
<td>Power Substation</td>
<td>$3 \times 10^{-6}$</td>
<td>$3.3 \times 10^5$</td>
<td>0.997</td>
</tr>
<tr>
<td>Contact line (failure rate /Km)</td>
<td>$7.97 \times 10^{-7}$</td>
<td>$1.25 \times 10^6$</td>
<td>0.994</td>
</tr>
<tr>
<td>Transmission system (estimated for 200 Km)</td>
<td>$2 \times 10^{-5}$</td>
<td>$5 \times 10^4$</td>
<td>0.985</td>
</tr>
<tr>
<td>Train Hypothesis</td>
<td>$5.9 \times 10^{-5}$</td>
<td>$1.7 \times 10^4$</td>
<td>0.958</td>
</tr>
</tbody>
</table>
3.1. Command and control system architecture.

The High Speed system architecture is based on an hierarchical structure which, starting from a Supervision post of the whole rail network, branches out until arriving to the management of peripherical installations. A draft of this architecture is shown on fig. 1.

The Supervision Post (PSV) is the summit of High Speed hierarchy, where arrive all data collected to locate train position on high speed lines and, with help of proper optimization tools, to realize circulation control by means of Central Satellite Posts (PCS) which manage a complete route section.

They are displaced with a step of about 200/250 km; their task is to control traffic of the line distance by talking to Fixed Peripherical Post (PPF). The PPF are differentiated like this:

- Movement Posts (PM) displaced every 48 km and equipped with passing tracks;
- Cross-over Posts (PC) displaced every 24 km and equipped with switches for train passing between two running tracks;
- Junction Posts (PJ) equipped with switches for coming in/out operations;
- Technological Posts (PT) where apparatus for headway and safety ground to train transmission management are installed;

The PM, PC and PJ are service places for local command and control of yard equipments, switches, possible signals ecc. realized by means of apparatus (ACEI) which normally are telecommanded directly from PCS.

In those posts and in the PT it is realized also management of headway apparatus by concentration every 12 km.

Finally there is Peripherical Mobile Post (PPM) that is the train which interacts with PPF equipments from where receives the orders of headway and speed and which is connected with PCS.

The hierarchical levels of this architecture are connected by a dedicated telecommunication network which follows on his whole extension the high speed line.

It utilizes fiber optic and copper cables and transmission system with synchronous hierarchy (SDH) and with high level of equipments duplication, able to guarantee a full availability of data transmission on safety for signalling.

3.2 Utilized technologies

The command and control system planned for high Speed lines permits to guarantee an interval of about 3 minutes between two train running on the same line at speed of 300 km/h, even if the operation program is now realized with a maximum frequency of one train every five minutes.

It was based upon transmission on board of all fixed and variable information which permits to respect speed limitations dislocated ahead of the train.
On board it is realized the elaboration of collected information, the building of safety characteristic curve continuous for the speed control and connection with braking system. Main features are shown in fig. 2.

Wayside signalling system it was abolished in agreement with this architecture; however it is planned the visualization on board through a proper man-machine interface of all the information of target and speed useful to operating at 300 km/h.

In the service posts there are central static apparatus for the command and control of switches and for interface with headway system.

The apparatus are telecommanded by a Central Post (PCS) which realizes functions already developed in the present CTC technology and also some new additional functions concerning the circulation management.

The headway system is based on transmission on board of a digital message containing all the information useful to regulate in continuous way train running.

For information transmission two systems are utilized: the former continuous, formed by audiofrequency track circuits (1,5 – 3 kHz) and the latter discontinuous, dislocated at service posts or at line singular points.

The audiofrequency track circuit proceeds from technology already developed by SNCF of a circuit able to detect train presence and rail breakdown and has the characteristic of an electrical joint between contiguous track circuits which removes need of mechanical joint. The length of track circuits is about 1500 meters.

This track circuit is used by means of carrier modulation to transmission ground to train of informative message related to data useful to train to carry out in automatic way his protection.

The employed technology realizes a modulation with a number of modulating frequencies like necessary informative bit number. It is realized a digital transmission of a message with "0" and "1" corresponding at presence or absence of modulating frequencies.

The continuous information transmitted are related to:

- track circuit gradient
- distance by sight
- speed level and deceleration rates allowed

On ground the message transmitted over track circuit is verified continuously and in vital way by means of proper circuits which select the carrier and detect the modulating frequencies, giving in output the received message. The same circuits are used on board in the cab-signal to decode messages. The discontinuous system projected will employ a punctiform transmission system ground to train displaced in particular points of the line and at service posts and it will be formed by proper number of beacons.

The discontinuous system is employed to increase the information dispatched on board by continuous system and adds a message with data about:

- electric traction change
- lowering pantograph
- coming in going out from High Speed line
COMMAND AND CONTROL SYSTEM ARCHITECTURE

Fig. 1

COMMAND AND CONTROL SYSTEM SIGNALLING

Fig. 2
- tunnels presence
- special speed control
- changing track

Either continuous systems and discontinuous systems of line will be power telesupplied from technological posts, dislocated every 12 km where it will be concentrated the computer that realizes the headway software and their interfaces towards the other command and control equipments.

For management of PM, PC and PJ yard equipments the softwares of static apparatus are adopted according new technology that was developed by FS, in place of traditional electromechanical apparatus, for higher performances of modularity, maintainability and modifiability.

The static apparatus is equipped with a vital Centre which elaborates the software of Peripheral Units management.

These manage the carrying out systems of yard equipments, of track circuits and of discontinuous systems. The vital centre is also interfaced with the on Safety Centre situated in the Central Post (PCS). The Peripheral Units are managed with logic of vital processing 2/2 and have also a whole redundancy. This redundancy is not realized for the non vital equipments, because the eventual functional non availability of these parts does not causes a total system break-down.

In the service posts the man-machine interfaces are generally put out and they are turned on just in case of operator presence.

The safety criterion employed for static ACEI is defined "Equivalent - Fail Safe". It defines an equivalence between electromechanical fail-safe equipments and safety electronic systems.

3.3 Control Centre Structure

Each high Speed line section is managed by a Control Post (PCS) where the command and control functions are carried out for following areas:

- traffic
- electric traction
- maintenance and supervision

Traffic area is oriented at train circulation regulation with control (CTC) already employed by Italian Railways. They are:

1. Acquisition of telecontrol of all peripherical equipments and service post apparatus (ACEI);
2. Display at Central Post;
3. Exeuction of operative commands;
4. Codification and trasmission to peripherical post of commands defined at Central Post.

In normal operating the telecommands towards the PPF are realized in automatic way by computer on the grounds of knowledge of train circulation program and they not require therefore any intervention by central operator (not attended operating or Permanent Route).
In manual operating the Central Manager is able to telecommand directly all the equipments subjected to Central Control.

The whole situations of circulation is represented on painted display units.

It is present also Train Describer function, integrated by Train Number (NT).

Electric traction area realizes the telecommand and telecontrol of all the transformation substations, and parallel and division contact line posts. In the central post it is settled a console equipped with videographic man-machine interface and functions keyboard. The failure investigation functions are worked out there.

Maintenance and supervision area permits to organize the interventions of maintenance and supervision of all the equipments and telecontrol of auxiliary installations.

It is realized by means of a control place which is interfaced with traffic and electric traction areas and which allows the supervision of all telecommunications network and ground to train radio connection.

4 Compatibility and Integration with european Project

The European project ETCS foresees, as is well-known the standardization of a command and control system by UIC.

The specific sub-project Eurocab and Eurobalise have times of prototype development oriented to 1995.

The solution adopted for High Speed in Italy will be able to be integrated with Eurocab specifications as soon as these last will be defined.

This solution is not significantly different from French solution of TGV. Therefore compatibility problem will be widely solved because new european standards ETCS have as preliminary qualification the compatibility with existing systems, that will be realized by means of proper interfaces.

A whole compatibility of High Speed Italian System with future european standard depends on the features of these standards and on their technical specifications.

In according to present trend of ETCS project which foresees the employment of digital 900 MHZ radio system, within Euroradio sub-project, it is possible to conclude that a future traffic command and control system based on radio transmission should be employed in high speed Italian lines as supply system, considering the carrying out planning of these projects.