Research and analysis of the most relevant causes of degradation of ERTMS based high speed signalling system

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Introduction

DECEMBER 5th 2009 became one of the most important dates in Italian railway history as it marked the official completion of a €32 billion project to build 661km of high-speed lines linking the north and south of the country. This network, which connects with Europe’s first High-Speed Line (HSL), the 254km Rome - Florence Direttissima, links the most important cities and serve around 65% of transport demand in Italy. Roma-Napoli, the first piece of the Italian brand-new high speed infrastructure operated by ERTMS without any other fall-back system, was launched in commercial service on December 2005. More than 8 million kilometres have been run since with ERTMS.

Figure 1– Italian High Speed line

RFI high speed is a fixed block radio based system which provides continuous supervision. The line is divided into a number of audio frequency track circuit. Signal are not provided on the high speed line but only signposts are install to identify the start/end of the sections. The city junctions between conventional...
and high speed line are still operated by national ATC system + ETCS L0. RFI plans in mid time term to upgraded said junctions by ERTMS to operate seamless the passage through the cities. 10 RBCs are provided for the four section of the route, these are duplicated by other 10 RBCs used in cold stand by. The on board system integrates ETCS + STM SCMT (National ATC system) : one DMI will be able to manage both system. ERTMS fitted section are operated at 300 Km/h per 20hrs/day whilst 4hrs are dedicated to maintenance. The maximum testing speed on the Italian HSL line has been reached into one of the Bologna-Firenze hsl tunnel at 362 Km/h by the ETR 500 testing train Y1. A fleet of 120 trains is currently fitted with ERTMS + STM SCMT (Sistema Controllo Marcia Treno). - On Milano - Bologna and Bologna - Firenze HSL multistation interlocking system is installed. GSM-R cell coverage redundancy provided as shown

Figure 2 – GSM-R redundancy coverage scheme on Italian High Speed line

Every basic element of the ETCS+GSM-R+SDH systems are double (or triple) redunded. The following quantitative reliability requirements have been specified by RFI for the trackside integrated systems enclosing GSM-R+SDH+ETCS:

<table>
<thead>
<tr>
<th>Immobilising failure (failures which affect train service)</th>
<th>mean downtime per year = 8 m</th>
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<tbody>
<tr>
<td>Service failure (failures which do not affect train service)</td>
<td>mean downtime per year = 1h 9m</td>
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Table 1 – RAM parameters (RFI requirements)

At present 124 train per day operate on the Italian HSL by means of ERTMS.

The integrated ETCS+GSM-R+SDH system in operation since 2005 comply with the requirements reported on table 1. The percentage of faults to ascribe to ERTMS is < 5% out the overall set of system faults.
Activities of research, analysis and removal of the main deterioration causes of ERTMS system on Italian High Capacity / High Speed line consist of:

1. Detect the trains that have been late because of signaling, location where failure occurred and head train locomotive
2. Download of ERTMS system diagnostic data
3. Analyze diagnostic data and ascribe failure to someone or something
4. Estimate the frequency of failure categories and the impact on railway traffic
5. Detect technological and procedural corrective actions or mitigations

Information referred to section 1 are obtained by a tool that supports traffic management process named PIC (Traffic Embedded Platform). Train crew that are involved in railway traffic monitoring write on the PIC a first information about delay reason.

If delay on PIC is ascribed to a signaling system failure, consultation of appropriate data base has to be done in order to extract the Radio Block Center that has jurisdiction in the place where failure has occurred and the STB (On Board Technological System) of the head train locomotive. After that, thanks to web applications, diagnostic data have to be downloaded (as referred to in section 2). Analysis of diagnostic data (as referred to in section 3) consist in detection of the moment when ERTMS/ETCS On Board Sub System commands the breaking and in check messages (Euoradio) exchanged between On Track Sub System and On Board Sub System and received on board from Eurobalises placed on the line in previous moments. In this way it is possible to ascribe delay to On Track or On Board Sub System failure or to air-gap between them.

Available diagnostic data are:
- Log RCB ETCS containing radio messages that RBC sends and receives from EVC
- Log EVC ETCS containing:
  - Radio messages that EVC sends and receives from RBC
  - Telegarms that EVC receives from Eurobalise
  - Results of EVC algorithms in terms of:
    - Function that start the breaking
    - Command of breaking
    - Speed limits
- Log JRU/DRU (Juridical/Diagnostic Recorder Unit) containing juridical and diagnostic events specified in UNISIG ERTMS/ETCS Class 1 subset 027.
- Log DIS (Driver Information System) containing guide events

Failure causes are grouped in categories and for each of these:
- Is estimated the impact on railway traffic (referred on section 4) with:
  - Occurrences number
  - Delay minutes
- Is proposed a solution /mitigation to the problem (referred to in section 5) that can be:
  - Technological
  - Procedural/Normative

Finally, after solution/mitigation implementation, efficacy is estimated thought observation of corresponding failure categories trend.

The graph1 shows the flow of the above activities.
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Graph 1 – Data acquisition system

The following graph (graph2) shows the signalling anomalies found during the observation period (from the 1st of January 2010 to the 28th of February 2010). These signalling anomalies are classified as:

- TNV_contact elapsed: represents the cases in which it fails the check by the vitality of the SSB radio channel
- Radio re-connection denied: represents the cases in which the radio link between RBC and SSB does not settle or stop
- HO by one MT only: represents the cases in which the SSB performs the Handover between 2 RBC with a single Mobile Terminal available
- TRIP (ERTMS): represents the cases in which the SSB ERTMS switches in TRIP mode (exceeding the End Of Authority, Unconditional Emergency Stop reception, etc.)
- L0-STM/L2 transition: represents the cases in which the train had difficulties in the historical-line/AV-line transition or viceversa (no opening or untimely closing of the border signal)
- DMI shut down: represent the cases in which the SSB DMI shut down
- Balise consistency error: represent the cases in which there was the loss of a balise, the receipt of a wrong telegram
- TRAIN-TRIP (SCMT): represent the cases in which operates the TRAIN-TRIP SCMT function (transition 75-AC or uptake a balise with red telegram). The SCMT system is the Italian STM national module.
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- SCMT error: represent the cases in which the SSB SCMT detect a vital track fault or on-board vital/fatal fault. The SCMT system is the Italian STM national module.

Graph 2 – Signalling anomalies
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Graph 3 – TNV_contact elapse events

As an example, the graph 3 shows the analysis about the TNV-contact related to the AV line Bologna-Firenze (activated in December 2009). We can see that the numbers of trains with at least one TNV-contact elapsed decreases rapidly after the first month of practice.

At the start of commercial service we had some problems of lost radio communications, in particular we had events like figure 1 when there was a disconnection of OBS for MT reboot. This problem was not an only problem of OBS, because wasn’t a fault hardware or a bug software of MT but an integration problem between MT and GSM-R. In fact we had sometimes these events in particular points of line where we had a problem with a specific adjacency cell configuration of traditional line GSM-R and High Speed Line GSM-R and a firmware version of Mobile Terminal. We reproduced this problem in laboratory and changed MT firmware to correct this particular bug Sw triggered from a specific configuration of GSM-R network.

Figure 3 - Description: the train is running in FS when a loss of radio communication occurs.

1. While the OBS trays to re-establish the connection with the RBC the TNV_Contact parameter expires;
2. EVC orders the train to trigger the service brake;
3. The train starts service brake application about 5" after having received the related order;
4. The OBS reconnects RBC while the train is still braking (in the e.g. after 15 seconds) (*);
5. The OBS receives new data and message from the RBC;
6. EVC orders to the train to release the applied service brake;
   The driver also releases the applied brake;
   The OBS sends a new position report to the RBC and the RBC takes it into account;
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When the applied service brake expires the train step by step reaches the maximum allowed speed in accordance with the available MA in FS.

*RBC waits 120 seconds before considering the train as train “Mute”. With the train in this condition the RBC cancels it from his database.

Another problem was an OBS odometric degrade in particular situation like raining or snowing. In these situations some trains had some adherence problems (like slip/slide events) and we detected some linking problems with balises or CES (Conditional Emergency Stop) accepted for Shadow section’s functionality (fig.2). All the monitoring and diagnostic sub-system of the network have been used to collect and sort data related to faults/error and degraded modes of ERTMS and related sub-systems. All trains at the end of mission execute a download of OBS log file via GPRS to a central database; in this mode we have all data for faults analysis or maintenance. These logs are very important because with a specific tool simulator is possible reply the run of train and to study the behaviour of OBS. To resolve the odometric question were been replied all runs of a specific period in laboratory and was been done a complete tuning of odometric parameters to improve the behaviour of odometric algorithmic during a slip/slide events.

![Figure 4 - CES management in shadow section and odometer accuracy](image)

Conclusions

The ETCS is the future of railways and is the automatic train travel control and protection system of today. The FS group has given great importance to this European railway research project and was the first to apply it, integrating it with its investment plan and organisation. The positive operating feedback and the continuous technological development performed together with our European partners make Italian State Railways one of the leaders in the ETCS sector. Progress has also been made in the rest of Europe in the last years in both testing and implementing ERTMS which proved to be very reliable and effective for commercial high speed operations. The fault analysis carried out in Italy but also in other European countries proves that the two most important field of research and improving are the radio data transmission system (especially when it comes to deal with enhance data transmission capacity resources - data and voice - available) and odometry which is really the ‘core’ of each ATC system.