Simulation of the railways control and protection ERTMS / ETCS; levels 0, 1 and 2

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Abstract

Simulation of railways control and protection systems allows the performance of different research tasks at low cost. The possibilities range from the design of the overall system to the planning of the allocation of trackside equipment, checking their influence over the line movements.

In this case, simulation of ERTMS / ETCS (European Rail Traffic Management System / European Train Control System) system is especially interesting for its novelty. One properly design simulator would allow to check the technical specifications for finding contradictions that may be introduced during the design of the system, and their subsequent correction. Employment of the simulator for the implementation of the driving and circulation rules is possible too. One simulator would definitely be the essential tool for the final step between the design and the implementation of ERTMS / ETCS.

In this paper, one ERTMS / ETCS simulator is presented. This tool is developed under Visual C++, using the power of Object Oriented Programming, and is organized in several applications, which communicates each other by means of the CORBA standard. System Requirements Specifications written by the members of the UNISIG group are fulfilled. Any line configuration in order to reproduce different scenarios is allowed. In this way exercises may be run in the simulator to obtain information about the system and reach the objectives listed above.

In the simulator, different equipments of the ERTMS / ETCS system are clearly separated in trackside and trainborne equipments.
equipment, the European Vital Computer (EVC), the Driver Machine Interface (DMI) and two antennas one for the Eurobalises information and the other for the radio (GSM - R) information, among others, have different modules in the simulator. In the trackside equipment that is simulated the followings may be underlined: Eurobalises, Lineside Electronic Unit (LEU), Euroradio and Radio Block Centre (RBC). This equipment may be configured to operate in levels 0, 1 and 2.

The simulator may be connected to a model cab or to a virtual cab. This last option consists in a photo realistic representation of the cab, in which the different elements may be operated directly over the image by means of the mouse or a touch screen. One realistic 3D model of the line environment is included in the simulator in order to obtain a complete immersion of the user in the exercise.

The ERTMS / ETCS components of the simulator presented in this paper have being used in HERO project in years 2000 and 2001 as part of SIFAV simulator of RENFE.

1 Introduction

The railway as a way to organize the transport infrastructure, inside the regulatory frame of the European Union, creates new necessities that must be solved to assure the success in the management and the operation of railways. Inside the new integrated exploitation environment of the new high speed lines, the ERTMS / ETCS (European Rail Traffic Management System / European Train Control System) is found as the system to protect and control trains, as a new European Standard to specify the communications and behaviour of the systems that cooperate in the supervision of the train movements.

This paper presents the development of a simulator of the ERTMS equipment with an application to driving simulators.

2 System Architecture Description

The simulator consists of an architecture in which two main subsystems may be described separately. These two subsystems correspond to the equipment installed on board in one hand and the equipment installed in the track in the other hand. In the following, both subsystems are described, paying special attention to those modules that are specific of ERTMS / ETCS.

2.1 Trainborne Equipment

The following modules may be found in this subsystem: EVC (European Vital Computer), DMI (Driver Machine Interface), Train Systems, Cab, Visual and Antennas.
2.1.1 EVC
Onboard computer of the ERTMS. In the simulation is on charge of receiving the information from the trackside equipment, combining it with that introduced by the driver through the DMI, to obtain the working mode of the system and activate the corresponding functions. The EVC is in charge of protecting the movement of the train, preventing that the maximum speed is not exceeded at any point. In order to accomplish these functions, this module must communicate with the Train Systems, acting over the braking system if that is needed. The EVC module receives the information that is collected by the modules of antennas: Euro balise telegrams and Euro radio messages, and sends messages to the trackside equipment through the Euro radio antenna. Moreover this module sends information to the Recording System, which will record system and driver actions that affect to the running speed.

This module completely fulfils with Class 1 specifications (SRS v2.0) of the ERTMS / ETCS system. Levels 0, 1 and 2 are developed. All modes, except for STMs, are included. Transitions between levels and modes are included.
2.1.2 DMI
This module is in charge of presenting to the driver the information of the signalling system. This module interacts with the driver through a touch screen, allowing to introduce train and driver data and the mode under which the train will begin to move. As the EVC receives information from the Trackside, this information is processed and shown to the driver in this module. Communication with the EVC is bi-directional, not only received data is displayed, but it interacts with the driver asking for acknowledgement of particular notifications. System specifications used to develop the module are July 2000 version of the DMI.

DMI functions implemented may be divided in three groups:
1. Graphical representation of system information. All the system information is presented in one screen to enable the complete vision of the DMI. The graphical representation of the ERTMS information is arranged in different areas: Area A. Brake Details, Area B. Speed Information, Area C. Maintain Speed, Area D. Planning, Area E. Monitoring, Area F. Driver Input.
2. Reproduction of audible information. Sounds are produced when some information is received or the driver carries out some actions.
3. Data introduction to send to system. The driver may introduced information to the simulation system by the data entry procedure, requests of supervision mode change and acknowledgements.

2.1.3 Other modules of the trainborne equipment
The rest of the modules that form the trainborne equipment of the simulator are:

Train Systems: this module includes all the functioning logic of that train equipment needed for a functional behaviour of the rolling stock, together with traction and braking characteristics. Each cab presents a number of procedures to start up the train, traction, braking, etc. which functionality is implemented in this module. It interacts with the EVC, from which it receives the actions that must be done over the braking system and to which it sends the positions of the traction and braking elements together with the velocity, so that the EVC is able to make a tracking of the train movement and calculate the braking curves. Train dynamics are included in this module.

Cab: this module is formed of the interfaces that are presented to the real or virtual cab to control the elements. All the controls that represented in the model cab, with the same working possibilities that are presented there, have an implementation here. The Cab modules only have communications with Train Systems, but in a bi-directional way, so that driver actions are sent and behaviour of the Cab, according to the logic implemented in Train Systems, is returned.
Visual: this module is in charge of presenting to the driver a realistic three-dimensional environment of the line on which the train is moving. It includes representations of the geometry of the track, signals, tunnels, overhead contact line, bridges, points, stations, etc. together with a representation of the landscape at both sides of the tracks. This module receives information of the Trackside module to represent the train at the corresponding point and velocity.

Euroradio Antenna: this module is receives information from the Trackside module by means of a direct connexion with the Euroradio module and sends it to the EVC, moreover it is able of passing information from the EVC to the Trackside system by the same connexion. It is employed in level 2.

Eurobalise Antenna: this module is receives information from the Trackside module by means of a connexion with the Eurobalise module and sends it to the EVC. It is employed in level 1 and 2.

Recording system: receives the fundamental information about train movement under ERTMS system and storages this information.

2.2 Trackside Equipment

The following modules may be found in this subsystem: Infrastructure Management, Infrastructure, Track Circuits, Interlocking, LEU, RBC, Euroradio, and Eurobalise.

2.2.1 LEU
LEU (Lineside Electronic Unit): receives information from the Track Circuits and the Interlocking modules and generates the indications in the track signals.
These information is sent to the EuroBalises module to be transmitted to the train. It is used in ERTMS level 1.

2.2.2 RBC
RBC (Radio Block Centre): receives information from the Track Circuits and interlocking modules and generates the radio messages with the Movement Authority for each train. These are sent to the EuroRadio module to be transmitted to the trains. It is used in ERTMS level 2. This module allows interaction with the user to generate specific messages.

2.2.3 Other modules of the trackside equipment

Infrastructure Management: this module is in charge of receiving the velocities and spaces of all the trains and positions them in the line. It communicates with each of the trains and the Infrastructure.

Infrastructure: this module contains the information of the line geometry (curves, gradients, tunnels, etc) and the position of each element: track circuits, switches, etc. together with the position of the trains from the Infrastructure Management. It is communicating moreover with the Interlocking and the Track Circuits.

Track Circuits: this elements represent the actual track circuits in the line. Their function is to register the position of one train and send this information to the signalling system: by means of the LEU or the RBC, depending of the level of application. Therefore communications with the Infrastructure are implemented for receiving positions of the trains and track geometry and with the signalling elements to send the occupation.

Interlocking: this module assures that the train movements are safe. It is based in the track layout, signals and points, together with the chart of movements and incompatibilities. From the routes of each train and the incompatibility of routes, Movement Authorities are generated and send to the signalling system, through the LEU or the RBC. A communication channel with the Infrastructure is used to receive the position of trains, another one with the signalling elements and finally some interaction with the user exists to introduce the desired routes for each train.

EuroRadio: transmission system based on GSM standard. In the simulator it is implemented by means of a direct software connexion. It is employed to transfer information between Trainborne and Trackside ERTMS subsystems, in level 2, in both directions. Therefore the communication channels are one to the RBC and another one to the EuroRadio Antenna.

EuroBalise: transmission system based on magnetic coupling. In the simulator it is implemented by means of a direct software connexion. It is employed to transfer information between Trainborne and Trackside ERTMS/ETCS subsystems, in one direction. Therefore the communication channels are one to the LEU and another one to the EuroBalise Antenna.
3 ERTMS simulation

3.1 ERTMS levels

Although five levels have been defined for the operation of ERTMS, only levels 0, 1 and 2 are available in this moment in the simulator.

3.1.1 Level 0

This level is activated when the train is in a simulated line without ERTMS equipment. The Movement Authorities (MA) may be shown to the driver by means of side signalling. In this level the simulation module EVC, is only active to receive data from the Euro Balises, if they are installed in the line, to order a level change and to control the top speed to which the train is allowed to move. This speed will be the minimum of the maximum speed of the train and the maximum speed for level 0. In this level the ERTMS trackside equipment introduced is restricted to Euro balises to order level transitions.

3.1.2 Level 1

In the simulator, this level has been implemented as a point transmission system added to another signalling system that employs side signals. The Movement Authorities are generated in the ERTMS trackside equipment of the simulator and sent to the trains by means of the Euro balises. Supervision of maximum speed and end of the MA is made continuously.
Simulation includes the use of Release Speed, which is a consequence of the discontinuous transmission, and is needed to approach to a red signal.

In this level the simulator includes the Euro balises, in-fill balises are also considered, and the Lineside Electronic Unit (LEU) for the Trackside equipment. Their main task is to elaborate the MA with the data received from the signalling system and send them to the trains together with the information of the line.

On the other hand the Trainborne equipment includes the transmission modules to receive the information sent from the track. The main functions for this level are to receive information of the MA and track data, process the data to obtain the maximum speed at each point, calculate the Dynamic Speed Profile (DSP) considering the braking characteristics of the train, continuous supervision of the train speed, intervention on the train brakes if necessary and inform the driver through the DMI.

3.1.3 Level 2
The simulation of level 2 of ERTMS is based on a continuous transmission system by radio that works as a support system to the signalling system.

In this case the MA are generated in the trackside equipment of the ERTMS and sent to the trains by the Euro radio. The supervision of the maximum speed and the end of the MA is continuous. Moreover to the communication through the radio, Euro balises are also used as references in the line to situate the trains.

In this level a new module is added: Radio Block Centre (RBC) this element knows the position of the trains in its area and elaborates and sends MA and information specifically for each train. The data needed to that function is received for the field elements as track circuits, interlocking, etc.

In this level, as continuous communication is available, no side signalling is needed and therefore the Release Speed is eliminated in the simulation.

The simulated trackside equipment includes RBC, communication equipment (GSM-R) and Euro balises. These elements have the following main tasks: identification of the trains, follow the movement of the trains, calculate the MA for each train, send the messages to the trains and finally control the transitions between two RBCs.

The simulated trainborne equipment includes transmission modules for the Euro balises and the Euro radio. The main tasks 1 are: reading the Euro balises and sending the relative position to the RBC, receive information of the MA and track data, process the data to obtain the maximum speed at each point, calculate the Dynamic Speed Profile (DSP) considering the braking characteristics of the train, continuous supervision of the train speed, intervention on the train brakes if necessary and inform the driver through the DMI.

3.2 Class 1 functions implemented in the simulator
The list of ERTMS Class 1 functions that the simulation system performs is:
- Start Up & Test
- Train Data Entry
- SSP calculation
- DSP calculation
- Release speed calculation
- Train location
- Speed calculation and speed indication
- Display MA and SSP on DMI
- Supervision of MA and speed
3.3 Functioning Modes of the ERTMS / ETCS in the simulator

The list of ERTMS Class 1 modes that the simulation system performs is:
- Isolation
- No Power
- System Failure
- Sleeping
- Stand by
- Full Supervision
- Unfitted
- Staff Responsible
- On sight
- Trip
- Post trip
- Non leading
- STM European mode
- STM National mode
- Reversing

The simulator includes transitions between modes as specified in the SRS following the incompatibility and priorities table.

Figure 4: Image of the simulator prepared in cooperation with Siemens Spain.

4 Conclusions

In this paper the development of a simulation system for driving of high speed trains on lines equipped with ERTMS / ETCS has been presented. The ERTMS / ETCS components of this system have been used in HERO project in years 2000 and 2001 as part of SIFAV simulator of RENFE.

The different modules of the system have been implemented in Visual C++ modelling language, with communications between them programmed in CORBA standard. All the interfaces are designed and implemented following the specifications of the system, therefore they are easily interchangeable by new interfaces that allow the update of modules or they substitution by real elements.
References

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