ERTMS/ETCS test simulation bench

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Abstract

Due to its safety characteristics, signaling equipment requires a great amount of testing and validation during the different stages of its life cycle, and particularly during the installation and commissioning of a new line or upgrade of an existing line, the latter being even more complicated due to the short engineering periods available overnight.

This project aims to develop a tool to reduce the above-mentioned efforts by simulating a whole railway environment, fulfilling the interfaces between subsystems and elements of these subsystems, and later interchanging simulated elements for real ones.

In this way, a testing environment for signaling equipment and data has been developed for the ERTMS/ETCS system. The aims of the project that were set out at the beginning of the development and completed with the present simulator are as follows:

- Real ERTMS/ETCS equipment trials and integration: RBC, EVC, etc.
- Other signaling elements trials and integration: interlockings.
- ERTMS/ETCS track data validation.

In order to achieve these objectives, various simulation applications have been developed, of which the most important are the following: EVC – DMI, Infrastructure, Manned train, Automatic trains, Virtual Cab, Train systems, Visual, Planning and Control Desk, Movement Tables Simulator, etc.

This system has been developed, and is currently adding new modules and functionalities, for companies of the Invensys Group: Westinghouse Rails Systems in the UK and Dimetronic Signals in Spain, which are using it for the new ERTMS lines under their responsibility.

Keywords: computer techniques, management and languages (simulation), advanced train control (ERTMS), equipment test.

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1 Introduction

The ever increasing expansion of railways in recent years together with the appearance of new signaling and rail traffic management systems, such as ERTMS/ETCS, means that both railway infrastructures and the on-board equipment need to be brought into service as quickly and safely as possible. Therefore, in order to obtain a safe and reliable operation, numerous tests need to be performed, but the high costs of infrastructures as well as rolling stock make it extremely difficult to immobilize both in order to use them for testing and training. For this reason, and because sometimes it is impossible to create high risk situations to demonstrate the procedure to follow, the use of simulators is more than justified in the world of railways. Within the scope of railway simulators, we can find different functionalities, such as driving simulators and operational simulators, for testing real equipment, and analyzing data, etc.

The main aims of the project with which we are dealing, are to develop a tool to reduce the effort needed to bring a new line into service, and at the same time avoid immobilizing infrastructure and rolling stock. The tool may even be used for carrying out tests prior to the physical existence of the new line. For this reason, our simulator is included among those developed for testing real equipment and analyzing data. In order to develop the simulator, all the elements needed as well as their real interfaces have been simulated, it being possible to replace each of these elements by their real equivalents.

In order to attain these goals, a test environment for signaling and data equipment has been developed within the ERTMS/ETCS system. The aims set at the start of the project, which have been completed with this simulator, are as follows:

- Integration and testing of real ERTMS/ETCS equipment, such as: RBCs, EVC, etc.
- Integration and testing of other signaling elements, such as: Interlockings, LEUs, etc.
- Validation of ERTMS/ETCS track data.

2 State of the art

2.1 ERTMS simulation

Having analyzed the available ERTMS simulators, as well as their applications and current status, the following may be mentioned:

- EIRENE – ETCS Simulator [1]: this is a railway tool that emulates the behavior of an ERTMS/ETCS train. The nucleus of this simulator is the scenario, made up of tracks, trains and events. In the initial stage the operator configures each element of the scenario so as to be able to move the simulated train in a second stage. This simulator may be used for several purposes:
    - Testing and development tool.
    - Evaluation tool.
    - Interactive demonstration tool.

- ERSA – ERTMS/ETCS Traffic management Simulator [2]: ERSA is currently developing an ERTMS traffic management simulator. The aims of this simulator are multiple:
    - Provide a test environment for conflict detector and conflict solver.
    - Provide a tool for ERTMS line capacity assessment.
    - Provide a validation environment for RBC in laboratory.
- AEA Technology [3]: AEA Technology Rail has developed an ERTMS simulator and this could be used to laboratory test the adhesion management system with simulated inputs or inputs derived from the 'shadow' trial. In that way the relative weighting of the various inputs may be adjusted to replicate as close as possible the actual service conditions.
- ERTMS MMI Computer Based Training [4]: The CBT introduces drivers to the new advanced train control system and simulates the MMI using a series of typical user scenarios. The driver learns to handle the MMI in a guided tour, then exercise his acquired knowledge in a scenario based simulated environment and proves his knowledge in a controlled test.
- SIMUFER [5]: To cover the needs of SNCF, Oktal has designed and realized SIMUFER. Equipped with cabin motion, a sound and illuminated environment, and 3D images. It enables you to study and validate different systems, cabins and driver's desks at the various stages of their design and in relation to the different fields of study. In the field of infrastructures, SIMUFER helps you to define, test and validate the specifications of the entire control check system, in terms of the vehicle-infrastructures interface.
- Giftren [6]: was developed by CITEF as an operation simulator, and later ERTMS features were added to check its functionality against a required level of performance. Full models of the trackside elements were developed and limited for the trainborne elements.
- SIFAV [7, 8]: this is an ERTMS/ETCS simulator developed for RENFE directed towards driver training, and complies with ERTMS/ETCS Class 1 system specifications (SRS 2.0.0) and CENELEC specifications. All driving modes and levels are implemented, as well as the transitions for both mode and level.
- EADS Train Simulators [13]: Train driving simulator developed and manufactured by EADS for Trenitalia is designed for training, evaluation and assessment in the fields of fundamentals in driver technique, practice in correct handling, driving in adverse conditions, and operation under ERTMS.

2.2 Test benches for railways

As for the test benches for testing equipment and interoperability among equipment, etc., the following may be mentioned:

- Trials for Demonstration of interoperability of ETCS components [9]: EMSET (European Madrid-Seville Eurocab Test) is a Project sponsored by the European Union. The main purpose is the initial system integration as well as the validation of functionality and technical interoperability of components and sub-systems of the new standardised European Train Protection and Control System ERTMS/ETCS.
  Some of the interoperability checks that were done during this project are:
    - Eurobalise Interoperability Verification Tests.
    - Euroradio Protocol Interoperability Verification Tests.
    - Eurocab Functional and Interoperability Tests.
- Moog [10]: Moog has developed a complete electric system named the European Railway Train Monitoring System for Trenitalia. This system tests the speed of the train and simulates the behaviour of the train equipment during normal use on the line.

2.3 Simulator use in ERTMS.

The use of simulators within the scope of ERMTS for validating and testing equipment, data and technical specifications, is fully justified, not only by all the advantages set out in the points above, but is also justified by the following documents, where it is literally stated:

- [11] Interoperability constituent suitability for use assessment: If permitted by the relevant standard(s), the suitability for use can be assessed by simulation methods (such as on a test bench or on a test circuit). The conditions of acceptance are specified in this(ese) standard(s).
- [12] Interoperability Constituents: In the case of suitability for use, these specifications will indicate all the parameters to be measured, monitored or observed, and will describe the related testing methods and measuring procedures, whether in a test-bench simulation or tests in a real railway environment.

3 System architecture design

In order to meet the previously presented aims, a software structure has been developed, as shown in Figure 1, made up of different modules, each of which corresponds to a real element and is thus replaceable by such an element, so as to be able to test the working and interoperability of each one of these elements.

Of the different elements developed the following are worth pointing out:

- EVC - DMI: with this module the ERTMS/ETCS on-board equipment is simulated (European Vital Computer) which complies totally with ERTMS/ETCS class 1 system specification (SRS 2.2.2), and the interface of this is also simulated with the driver (Driver Machine Interface) which complies with CENELEC specifications. All the ERTMS driving modes and levels have been implemented, together with the transitions of both mode and level.

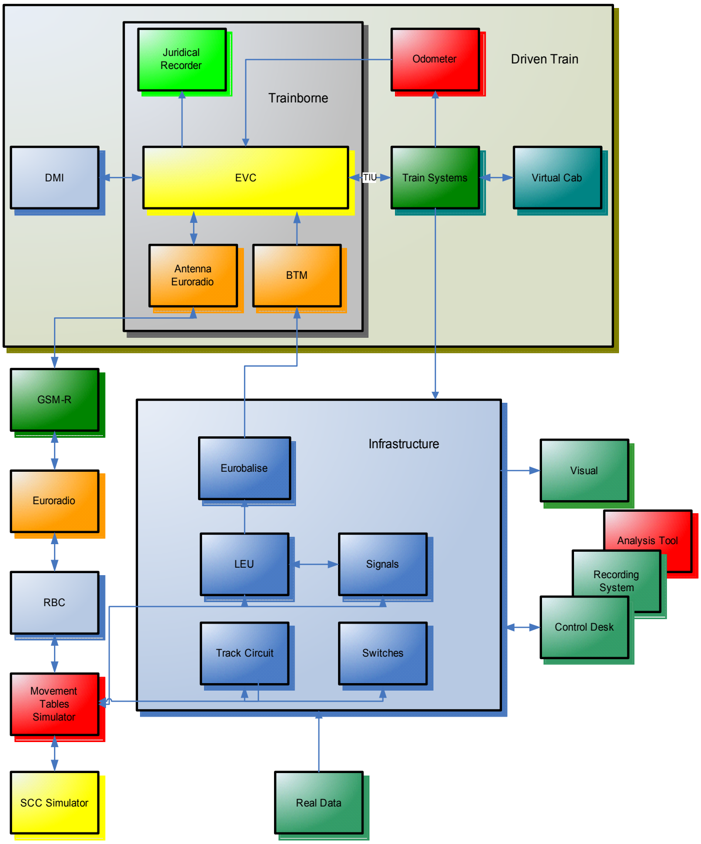

Figure 1: General layout of the ERTMS / ETCS Simulator.

- Train Systems: the mission of this application is to simulate the train's electrical and pneumatic performance; to this end the electrical and pneumatic circuit diagrams have been used, simulating each of the elements included. The vehicle dynamics have also been simulated.
- Virtual Cab: in order to be able to drive the train without any real controls being needed, a photo-realistic representation of the real cab controls has been developed where all the levers and buttons necessary to start and move the train can be activated.
- Infrastructure: this is automatically generated from a configuration file containing a description of all the elements making up the infrastructure, using a specified language: track circuits, points, balises, signals, etc. The logic of each of these elements as well as their functionality has also been simulated.
- Visual Environment: this attempts to provide a realistic environment for the driver. It is a three-dimensional system whose viewpoint corresponds with that of the manned train driver. It includes, as

realistically as possible, all the elements that are typical of the infrastructure: track geometry, track circuits, points, signals, balises, tunnels, stations, catenary, etc. The visual environment is produced automatically using the same configuration file used for generating infrastructure.

- Manned Train: it is possible to have a manned train running on the track. As we have already pointed out, the electrical and pneumatic diagrams for the train are realistically simulated, and by using the Virtual Cab, we are able to implement all the elements needed to drive the train (pantograph, traction and brake regulator, reverse drive, etc).
- Automatic Trains: it is also possible to have more than thirty automatic trains running on the line. The dynamics and signaling elements of these trains are exactly as for the manned train, but in this case, the driver's actions are simulated automatically. By using automatic trains, both the performance of the on-board equipment and the infrastructure can be checked. For example, the correct working of the RBC with several trains connected to it can be checked.
- Planning and Control Desk (PCD): this application allows the Simulator user to: generate, configure, launch, etc., the different scenarios. Among many possibilities, the features and starting out positions of the manned and automatic trains and some visual features can be configured.
- Movement Tables Simulator: This application simulates the actions of an interlocking, by using the data from its route tables. Its aim is to make all the necessary checks to establish and de-establish movements, and to supervise these movements once established.
- Analysis Tool: the use of this tool will lead to obtaining graphic results of real data fed into the simulator, in a convenient, fast and reliable way. We can also see how the on-board equipment reacts to receiving this data, and thus check that any data to be subsequently installed on the track will not produce any undesirable effect on the train signaling equipment.

As can be seen in Figure 2, in order to obtain a maximum integration of the real equipment, the communications have been separated into a separate module within each application (Interactive Data Language). This method ensures that the application structure does not change when real equipment is introduced.

The mission of the communications module is to manage all the communications of the relevant application. This module isolates the communications from the rest of the application. The communications process is as follows:

- The body of the application generates its data.
- The data is transferred to the communications module.
- The communications module codes it and generates a single structure that stores all the information.
- This structure is sent to the 'Host' and the module receives a similar structure containing data for the body of the application.

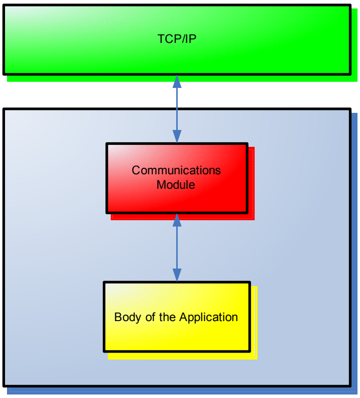

Figure 2: General layout of an application.

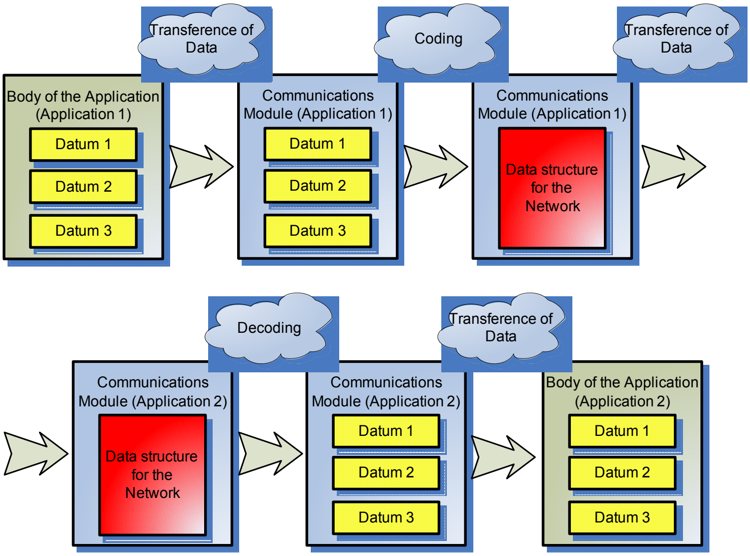

Figure 3: Communication between two applications.

- The communications module decodes this structure into simple data and sends it to the body of the application.

The simulator works in an asynchronous way so that the communications do not follow any pattern. Therefore, it is very important to have the communications well under control. To this end, the ‘Host’ has been developed, which is an application programmed in C++ whose function is to handle communications. Its mission is to tell each application where it can find the data it needs.

Figure 3 illustrates the communication process between two applications.

The body of the applications is based on CITEF components technology. A component is a DLL (Dynamic Linked Library) that carries out specific functions. For example, the function of a component that simulates a valve is to calculate pressures. All the components comprising the body of the application are stored in a Components Container.

The Variables Register is the name of the Components Container developed by CITEF. A component can communicate the status of a determined number of variables to other components in the same register. This is possible thanks to the fact that the variables register has a list of these variables with their values.

The communication mechanism is as follows:

- A component A tells the Variables Register that a variable A belongs to it.
- The variables register stores Variable A in a list.
- A component B, which wishes to know the value of variable A, tells the variables register that it wishes to be an observer of Variable A.
- The variables register stores Component B in the list of observers of Variable A.
- When component A changes the value of Variable A, the Variables Register communicates the new value to all the observers of Variable A.
- Any observer may try to change the value of Variable A, but this change is notified to component A, and this has to authorize the change. If the change is not authorized, the value of Variable A will continue to be the same.

Figure 4 illustrates the communication mechanism between the two components:

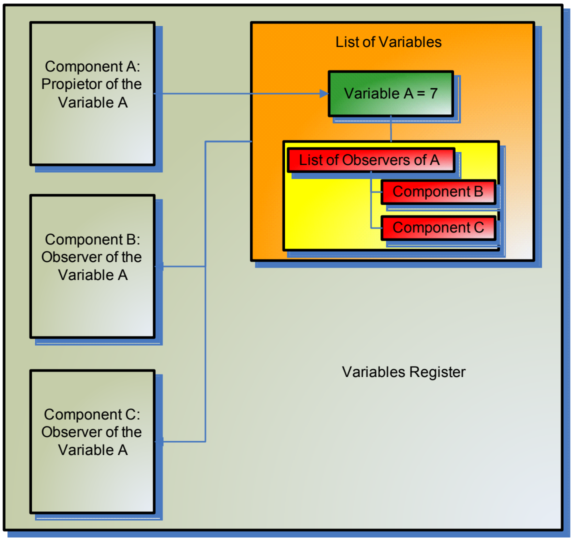

Figure 4: Communication mechanism between components.

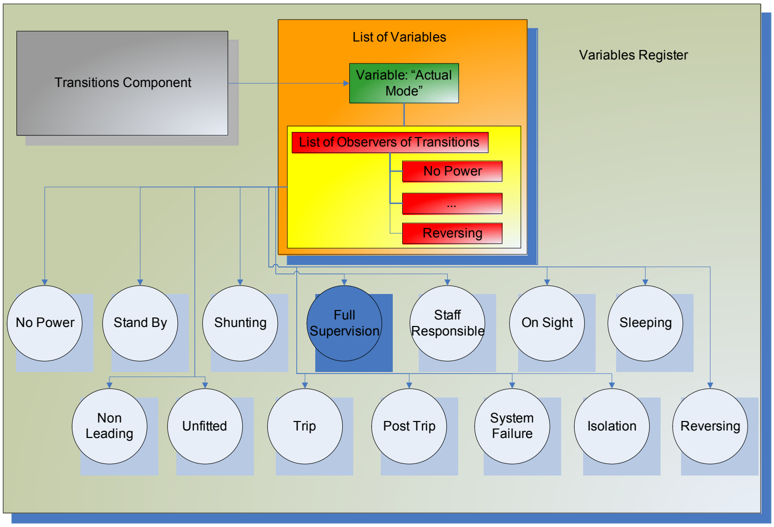

Figure 5: Transitions between modes.

4 Simulated elements: EVC

A clear example of how the above-mentioned architecture works, is the development of the mode transitions implemented in the EVC. The EVC has been developed as an automaton, which is in one state (depending on the current EVC mode) and changes to another state (mode) if certain conditions are met. At the same time, when the EVC is in a particular mode, it will have to perform different functions which have been implemented into different components. With this architecture, it is very simple to implement the EVC's internal operations.

Depending on the entries, the component that performs the transition publishes the mode it is in, and for each existing mode, we have a component. The component corresponding to the state indicated by our transitions automaton will be the one that is active and will supervise the functions to be complied with in that mode.

Therefore, as can be seen in Figure 5, certain components publish the different variables included in the transition table according to SRS 2.2.2, and the component entrusted with the transitions observes these variables passing to the different modes according to whether or not certain conditions are complied with.

5 Real elements: RBC

As can be seen in Figure 6, the body of the application is replaced by a module that translates real data to simulated data. The translation module translates real

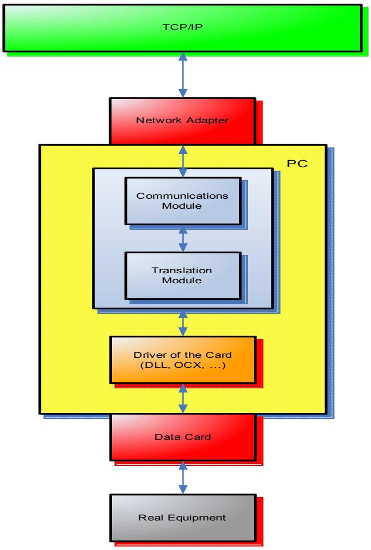

Figure 6: Data transmission layout between an application and real equipment.

data to simulated data when a communication is made from the real equipment to the application, and translates the simulated data when a communication is made from the application to the real equipment.

A clear use of real equipment in a simulator is that of the Radio Block Centre (RBC). In this case a real RBC Host is being used, and between this and the simulated equipment that is communicated with, the EVC, for example, a translation module is introduced whose mission is to capture the messages sent from the RBC to the EVC, clear them of the Euradio layer and protections, and transform everything into a 'language' that can be understood by the on-board equipment so that it may be sent to it. However, if the communication is made from the EVC to the RBC, what the translation module will do is transform the simulated data into real data while endowing it, among other things, with the protection codes and the Euradio layer, in order to subsequently send them to the real RBC. This procedure is shown in figure 7.

6 Advantages and functionality of the system

It may, therefore, be stated that the main advantages and functionalities of the system described in this article are as follows:

- A reduction in the efforts required to bring lines equipped with the ERTMS/ETCS system into service.
- Since neither the infrastructure nor the rolling stock need be immobilized in order to carry out tests, a considerable reduction in costs is obtained.

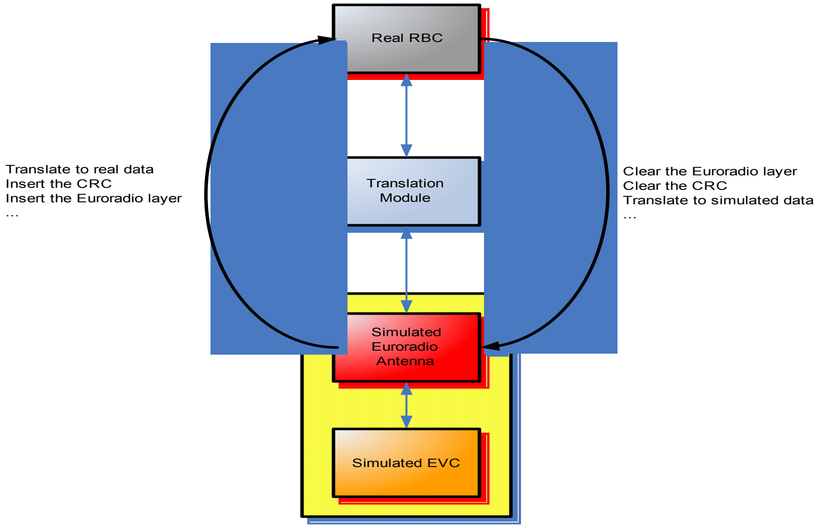

Figure 7: Layout of the system when a real RBC is integrated.

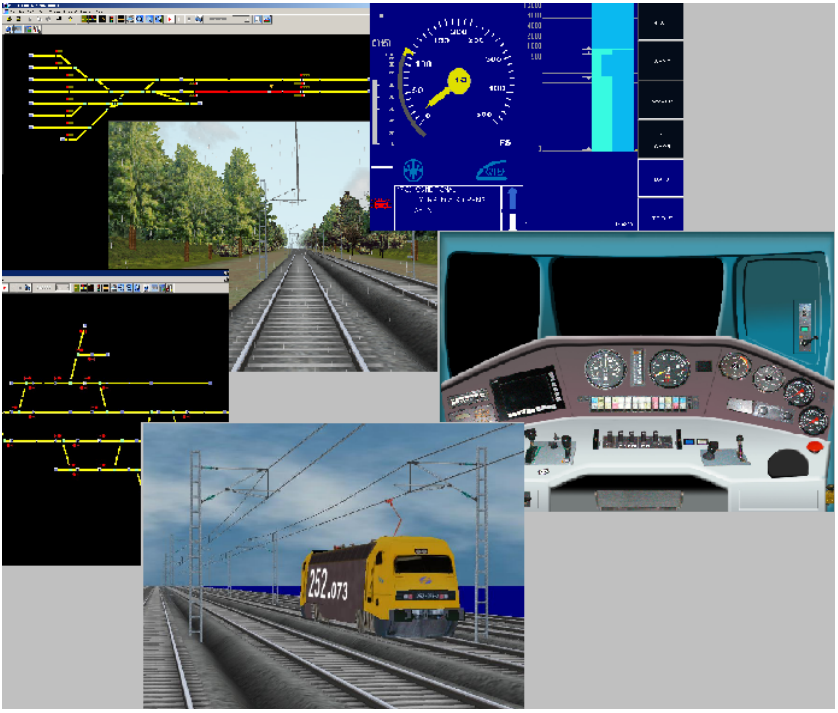

Figure 8: Some snapshots pf the simulation system.

- Since the same interfaces are used as with the real equipment, this means that functional and interoperability tests can be performed on real equipment, with the possibility of simultaneously including one or more pieces of real equipment.
- It may be used to verify trackside data before it is installed, and in addition, if need be, obtain results showing where the erroneous data is located.
- It may be used for training drivers in the ERTMS system.
- It may be used for training drivers to handle train equipment using the simulated cabs.
- It may be used to train SCCs operators.

7 Conclusions

Since the ERTMS/ETCS Test Simulation Environment developed by CITEF fully complies with ERTMS/ETCS Class 1 system specifications (SRS 2.2.2) and CENELEC specifications, as exactly the same interfaces built into real equipment have been integrated in the development process, it can guarantee that the behavior of the simulated and real equipment is absolutely identical.

Moreover, if we take into account that the use of simulators in a railway environment has been fully justified throughout this article, and more so in this particular example of an ERMTS environment, we may state that using this test bench tool is an overriding guarantee for bringing new ERMTS lines into service as well as ensuring that the different track and on-board equipment will run smoothly under absolutely any circumstances.

Being able to integrate real equipment in place of simulated equipment also guarantees their interoperability.

It is also a tool for preparing data, testing and detecting any possible failures in track data.

We may state that in spite of the development costs for this type of tool, the cost of track tests is reduced considerably thanks to this simulation environment, since the number of track tests is reduced, thereby reducing the use of infrastructure and rolling stock set aside for this purpose.

This system has been developed, and is currently adding new modules and functionalities, for companies of the Invensys Group: Westinghouse Rails Systems in the UK and Dimetronic Signals in Spain, which are using it for the new ERTMS lines under their responsibility.

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