Information technology for electrical system compatibility and interoperability problems on the European railway network

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Abstract

Interoperability between all subsystems of a rail network is a prerequisite for reliable and safe rail transport within and across national borders. The electrical compatibility of new railway vehicles with the existing power supply, signalling and vehicles, has more recently been found to be a major obstacle to reach this goal.

\textit{Electrical System Compatibility for Advanced Rail Vehicles (ESCARV)} [3] is a RTD project co-financed by the European Commission and the Swiss Government under the 4\textsuperscript{th} Framework Programme to identify main barriers and propose solutions.

Railway manufacturers, operators and research centres co-operate in ESCARV to establish a modelling framework of the complete railway system, enabling to predict and avoid interoperability problems before putting a system into operation, and to produce a set of design recommendations for new vehicles as well as input to new or updated European norms.

In particular, the User Group Task Force was set to improve and ensure the dissemination of the ESCARV approach and results to a wide set of users (namely railway network and operator companies, manufacturers not involved in the project partnership), establishing the so-called ESCARV User Group.

In this paper, the authors show the User Group objectives and introduce the Info Bank, the tool for sharing and achieving ESC knowledge.
1 Introduction

Promotion of environment-friendly, reliable and safe rail transport of passengers and goods within and across national borders is a major EU objective. In order to reach this goal, interoperability between all subsystems of a rail network is a prerequisite. Numerous technical barriers, such as different track widths, supply voltages, or signalling systems have long been identified.

The lack of electrical compatibility of new vehicles with the existing power supply, signalling and vehicles, has more recently been found to be an additional obstacle. Large regional transportation networks collapsed, electrical vehicle interaction caused protective shutdowns and delays, signalling systems and barrier crossings malfunctioned, information and telecommunication systems were disturbed, TV/computer screens were flickering. This was all due to a lack of electrical compatibility and interoperability of components in an electrical rail network (see Figure 1 and Figure 2). Most problems were introduced with the operation of new vehicles on existing lines. These effects have led to costly rework and delays for the manufacturing industry, and to deteriorated quality of service and capital utilisation for the railway operators.

![Signalling system malfunctioning](image1)

**Figure 1:** signalling system malfunctioning - an example

![Electromagnetic interference](image2)

**Figure 2:** electromagnetic interference
The problem the authors are dealing with (namely ESC) moves from the European railway open market, and consequently arose from the EC Directives on Interoperability.

For sake of example, ESC has different fundamentals:

- to allow trains running throughout Europe not to stop at the national borders neither for customs inspections, nor for technical constraints (signalling and power supply systems)
- to allow industries to get new market segments outside the “national borders”
- to guarantee the compatibility between different signalling/power supply systems within the same country and infrastructure segment

These considerations lead to an impressive challenge which the European railway society has to deal with. The objective of the European railway industry would be to allow railway network and operators to identify their requirements properly.

The achievement of this objective requires the co-operation of all the entities involved in this context. Manufacturers, railway and EU expectations should merge the different perspectives to determine common objectives and targets. ESCARV is the evidence that a team approach for problem solving is possible making industries and railways talk and work together.

2 ESCARV – The objectives

ESCARV comprises modelling of the railway system and its parts (such as substations, lines and vehicles), enhancement of the knowledge on interference mechanisms, tools for the prediction of potential problems, measurement methods and compatibility assessment of vehicles. This will shorten the vehicle design process while simultaneously ensuring wider compatibility and therefore higher quality of the product.

Three main technical aspects of the project deserve special care:

- numerous physical phenomena of different nature are involved: the system modelling integration could be very difficult
- the overall model complexity may be too high to be handled and a model reduction may not be possible without losing major effects [1]
- potentially dangerous situations could be identified by modelling, but not considered in standards and not be verifiable with measurements

Most important benefits expected after completion of the project are:

- For the equipment manufacturers
  - reduce costly rework and delays - reduce the risk of last minute changes resulting from ESC problems
  - shorten the vehicle design process and ensure wider compatibility and higher quality of the product
  - better data exchange between the various manufacturers on the same railway system
- a level playing field which opens up bigger market opportunities across Europe
- For the railway operators
  - shorten the acceptance period, leading to earlier introduction of new rolling stock
  - easier evaluation of tenders and technical specifications thanks to Europe-wide processes for assessing ESC
  - reduce the cost of the testing activities
  - improve quality of service and capital utilisation
- For the whole European railway industry
  - enhancement of the knowledge on interference mechanisms
  - new methods for prediction of potential problems
  - cost effective measurement procedures and compatibility assessment processes

In a quantitative way they could be lead to the 30% reduction in cost for demonstration of compliance and to the decrease of network outage from an expected 1h/year to 0.5h/year, resulting in a passenger benefit of 25 ECU per passenger for saved time/reliability of transportation to work and further increase in safety.

3 The actual results

The focus of the ESCARV research activities during the first two years of the project was on
- the development of the reference models of each railway subsystem [4]
- the computer modelling of the configurations tested during the field tests
- the characterisation in the lab and the computer modelling of signalling subsystems
- the validation of sub-systems models by means of the field tests and additional tests
- the validation of railway system models consisting of several subsystems

The following reference models had been developed:
- Line/Catenary for DC and AC systems
- AC and DC substation
- AC and DC vehicles (traction and auxiliary)
- Magnetic and electric field from the line (see Figure 3)
- Signalling: track circuit, impedance bond
- Pantograph arc
- Magnetic field under the vehicle body

Particular attention must be paid to the system integration issue. Modelling is performed with great care at the physical level rather than demanding it to software packages. Significant simplifications are done within known approximation, both in the component models and after integration in the system.
Uncertainties in modelling results are eliminated by applying different independent modelling techniques (e.g. deterministic, probabilistic) adequately supported by specifically conceived measurements [2].

![Figure 3: a typical result (H-field) coming from the ESCARV reference model](image)

In order to validate the models, two test campaigns were performed on the Italian and Swiss railway networks (see figure 4). In Italy, the tests were carried on the FS line between Terontola and Chiusi (28 km long); the AC tests took place on the SBB line near Zurich (15 km long). Each subsystem (loco, power supply, signalling) has been tested, recording time domain data of line voltages and currents, rail currents, loco mechanical and electric variables (up to 20 kHz) in several locations along the lines. Special locations have been arranged for measuring radiated fields, too. The comparison between simulated and measured data gave good results (see figure 5).

![Figure 4: ESCARV field tests on SBB network (Switzerland)](image)

Validation of the computer models proved to be a very demanding task. The validation of a large combined system, such as a complete railway line with power supply and vehicles, cannot simply be done by comparing measured results with test results. Many parameters are not sufficiently known, neither for the measurements, nor for the simulations. Repeated tests under virtually
identical conditions can give different results, because some of the unknown parameters (such as earth resistance, leakage to earth) may have changed. This was not unexpected. The validation of such complex models will not result in a simple 'valid' or 'invalid'. The validation shows the capabilities and the limits of the models. The restrictions of the models and of their use must be known, declared and respected.

![Figure 5: comparisons between calculated and measured data](image)

The models previously validated has been used in two real-world AC and DC applications
- investigate and demonstration of the stability in AC network (SBB)
- investigate of the interference between the 25kV 50Hz and 3kV DC lines (FS) [5]

4 Exploitation of the results: the Standard and the User group/Info Bank Task Forces

ESCARV is now focussing on the exploitation of the project results. In order to demonstrate compatibility with e.g. a signalling system the systems engineer (no matter under whose responsibility) needs the either of the following steps:

**Step 1.** comprehensive information about the railway infrastructure in order to work out suitable criteria for compatibility

**Step 2.** the compatibility criteria for the vehicles in the form of interference limits, duration, analysis methods

Today, all vehicle manufacturers and operators collect ESC relevant infrastructure information and maintain it individually (step 1). Uncertain or inconsistent interference limits form an increasingly critical barrier for true European interoperability. Although it may not be possible to agree on a common European interference limit, significant improvements compared with today's situation are possible. Their practicality has been demonstrated in ESCARV. Share infrastructure information and experience with the elaboration of compatibility criteria is sensible. Since electrical systems compatibility, in
particular signalling compatibility, is potentially safety critical, this information and the experience gained should not be kept as a competitive advantage. To achieve the standardisation of the interference limits (and of other compatibility criteria) might be a long term objective. With the evolution of vehicle and converter design technologies, it may become possible to design a vehicle capable of operating over a European limit.

The ESC Info Bank and the ESCARV User Group Task Force address the first step: to share the non competitive information and experience with electrical system compatibility.

The ESCARV 'Standards' Task Force and the AC and DC Applications address the second step: standardisation of criteria, methods and procedures.

4.2 Make ESCARV outcomes valuable for standards

Achieving true interoperability on a European network does not only require common procedures for vehicle/goods transfer between countries and common signalling system interfaces etc. It also requires common standards for assessment of electrical systems compatibility towards signalling, environment and power systems. Today this is handled mainly by CENELEC on the European level and by IEC/UIC on the world-wide level.

A special ESCARV Task Force has been formed in order to:

- improve and consolidate the results from the surveys of applicable standards presently in force and those in preparation
- establish direct contacts with all relevant CENELEC and UIC working groups
- collect the recommendations from the different ESCARV workpackages and explore the possibilities how they can be transferred to the standard working groups

Practical examples of this link are

- guidelines for the application of CENELEC prEN 50238 in compatibility cases (see figure 6)
- correlation between conducted interference and emissions in the range 9kHz – 30 MHz
- active participation in WGC11 of CENELEC TC9X (compatibility between vehicles and power supply)

A sensible approach to achieve full interoperability is to establish common standards (like prEN50121). Moreover, establishing common procedures for demonstration of compatibility (as suggested by the prEN50238) might reduce risks, costs and project delays. It is desirable that the various standardisation working groups are open and communicative. Any forthcoming standard or procedure, which later is going to be followed by everyone, should be treated like public property to make possible for interested parties outside the working groups to get access to drafts. The standards (draft or released) could be accessible via Internet in order to achieve a wider working forum and avoid failures at late stages.
4.3 Expand the ideas of ESCARV towards other organisations

ESCARV put together an impressive amount of skills, experiences and information. These are all needed in order to detect possible problems (Electromagnetic interference/incompatibilities) before putting systems (new railway lines – including signalling, power supply, TLC, etc., and rolling stocks) into operation. The ESCARV approach was to characterise systems, determine, design, implement and validate models of any subsystem, merge together under suitable conditions into a common environment. Such an approach revealed its potential, and the Info Bank is the tool to promote and extend the ESCARV "way" to other parties (i.e., non ESCARV members). The idea and vision of an ESC info Bank has been developed throughout the project. The first important step is to collect the relevant information and the next step will naturally be to share the information. The first step is something which all cross-border/industry projects are facing during contractual compatibility studies. The ESCARV approach will hence be to share for common use any ESC relevant information that is not proprietary. Non proprietary information could be track circuit models, network topologies, black-box models of vehicles and substations (e.g. input impedance).

The Task Force User Group and Info Bank was set to improve and ensure the dissemination of the ESCARV approach and results to a wide set of users (namely railway network and operator companies, manufacturers not yet involved in the project partnership).
The User Group is a wide group of parties involved in the ESC domain, including railways, manufacturers, consultants and research centres. The Info Bank is a relational database structured as a “hub-like” system. Three main hubs and associated areas have been identified for the Info Bank:

- Process (ESC main processes, their main phases and then each important step)
- Case History (universal units of documented experience)
- Infrastructure (data related to each railway system considered)

As an example, the following information are expected to be collected in the tool:

- ESC glossary, standards and literature
- Subsystem base models
- Design recommendations for new vehicles and infrastructure to guarantee their interoperability/electrical compatibility
- Validated procedures for modelling and assessment (e.g. as guidelines for application of European standards)

It is accessible via Internet and the user-friendly interface provides a guided access to the information.

After the end of the project, a sort of accompanying measure will be set up for the next two years in order to create the critical mass needed for keeping the Info Bank and the User Group alive. During this period all the User Group
members will contribute in defining the final role of the Info Bank and how to use it.

On July 6th and 7th 2000 a workshop was held in Brussels to introduce the Info Bank and to start the User Group activity. The workshop was addressed to industries and railway operators/owners, however also consultants and academic institutions, which were interested into Electrical System Compatibility topics, were invited to improve and share their experiences and skills with other interested parties. A panel session with key people was planned to stimulate the discussion between the participants and ESCARV members.

5 Conclusions

In the present paper the authors have presented the results achieved by the EU project ESCARV. In particular, the actual exploitation policies of the project have been highlighted. Two major action lines are going on: the first one is oriented to create a strong link between the project and the standardisation bodies; the second one is dedicated to disseminate ESCARV approach and results to a wide set of users. In particular, the *Info Bank* is the tool expected to have the highest value in terms of dissemination. This is an open software to gather and distribute ESC related information. Therefore, the success of the User Group policy, measured by the number of subscriptions and the utilisation of the Info Bank, is not only a success for the project, but for the whole European Railway community.

References


