Simulators for training locomotive drivers of Swiss private railways

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Since 2007 a number of Swiss metre-gauge railways have been training their locomotive drivers on simulators, using either a separate driver's desk linked to a simulation processor or the driver's desk of an operational vehicle. The Locsim simulation software of the Bern University of Applied Sciences in Biel/Bienne is employed in both variants. This software and its further development are described in this article.

Railplus simulation system for basic and further training of drivers

Railplus AG worked in close cooperation with the Bern University of Applied Sciences to build a mobile simulation system which has been in operation successfully since March 2007. The system is accommodated in a standard office container and is transported by road or railway to the particular application sites. This saves additional travel costs and expenses for users. Also, there is no need to provide rooms locally for accommodating the system.

The driver's cab is housed in a separate room inside the container. The driver's desk complies with the latest Stadler vehicle generation of the Matterhorn – Gotthard-Bahn (MGB) and Aare – Seeland mobil (ASm) railways. Apart from the usual controls and indicators most of the supplementary equipment used by the owner railways is also installed, for example equipment for rack operation, different train protection systems, and vacuum and compressed air brakes. The simulation display is projected with a beamer onto a 2.2-metre wide projection wall in front of the driver's desk.

Located behind the driver's cab is the instructor's workstation with two additional monitors and the console for operating the system. The rear section of the container provides room for discussions and theoretical instruction. Additional monitors at the discussion table enable the drivers who are not at the controls to follow what is happening.

The container is equipped with heating and an air conditioning system and supplied with power via a cable.

The idea of building the simulation system arose from the existing "Locsim" software of the Bern University of Applied Sciences and the need to be able to offer hands-on basic and further training without hindering railway operations. A total of eight Railplus AG participating railway companies and sponsors from the railway components supply industry were involved in building the system.

Railplus

The present Railplus AG was set up in 2003 by six Swiss private railways. It now comprises eight meter-gauge railways. The main purpose of this company is to exploit synergies and to define standards. In the various fields there are specialised teams concerned with specific subject groups. An important role is the joint instruction of train crews.

Experience gained since the system was commissioned has been consistently positive. The railways especially appreciate being able to practice particular operating conditions and situations which are possible otherwise only to a limited extent or even only during night-time operating breaks due to the steady increase in the frequency of scheduled services. Thanks to joint purchasing by the eight metre-gauge railways which together have a total of about 700 drivers, the capacity of the system is well utilized. Apart from being used by its owners the system is also available to third-party customers.

Maintenance and servicing of the system is undertaken by the Bern University of Applied Sciences and the Rolling Stock and Technology Department of Aare – Seeland mobil AG in Langenthal.

CJ training simulator

Most railways with tourism traffic have the fewest number of passengers in November. Less rolling stock and operating personnel is needed during this period. For this reason, most further training is undertaken at this time of year. As a non-member of Railplus, Chemins de fer du Jura (CJ) would, however, hardly have been able to lease the simulator at this particular time. At the end of 2005 it therefore came up with the idea of using a driving trailer as a training simulator. This trailer is barely needed in the slack period. The advantage of the driving trailer is the availability of the complete driver's cab. To make the situations as realistic as possible, all functions of the driver's desk must also be available during simulation (at a standstill). This applies especially to the speedometer which is fed directly from an axle-mounted sensor during operation. During simulation, a frequency converter

Bottom left: Railplus simulator container in Langenthal (photo: D. Fankhauser).

Bottom right: Interior view of the simulator container. View from the discussion room with the instructor's workstation through the glass partition wall to the driver's desk and projection of the view from the driver's cab. This view is also shown on the right-hand instructor monitor. The user interface of the simulation programme with the track layout is displayed on the left-hand monitor (photo: D. Fankhauser).

controlled by the simulation PC takes over this role. The multiple traction control cable offers access to most other vehicle functions. The brake pipe pressure is tapped at the automatic coupling and fed to the PC via a pressure measuring probe. The PC also controls the test device for the train protection system which has magnets positioned under the vehicle allowing the system to function like the original. The initial plan to project the view of the line onto a depot wall was abandoned after the huge drop in prices for flat screens and was replaced by a screen inside the driver's cab. This makes the simulation process independent of location.

The object of the simulator is to generate situations that can be arranged during normal railway operation only at great cost and effort and not without a certain safety risk. The following cases belong to this category:

- Block signalling faults,
- Signal faults,
- Vehicle defects resulting in serious delays,
- Barrier malfunctions at level crossings
- Incorrect operation of protection systems.

These disturbances can be implemented for the locomotive driver in the familiar environment. He knows the vehicle and since video films are used is also familiar with the line.

The training simulator is not used for clocking up the necessary driving hours during basic training but for training the reaction of the driver in the case of malfunctions.

Services provided by the Bern University for railways and industry

The Bern University of Applied Sciences has been working for more than ten years on the control and simulation of traction units. Work carried out in the control field mainly consists of replacing electromechanical control systems and electronic components for which spare parts are no longer available with programmable logic controllers. [1]

The simulation field was originally developed for these control system conversions to allow the operating behaviour of converted vehicles to be computed in advance. There are two fully developed simulation programmes available today:

- A train running programme for determining travel times, energy consumption and component temperatures in which a route is covered automatically by a train with optimized timing or energy consumption. This programme is used standardly by Stadler Rail.
- A driver's cab simulation programme (Locsim). With this programme, a traction unit can be driven over a given route by means of the usual interfaces between train driver and driver's desk (control elements and indicators).

The Locsim driver's cab simulation programme in the Railplus simulator

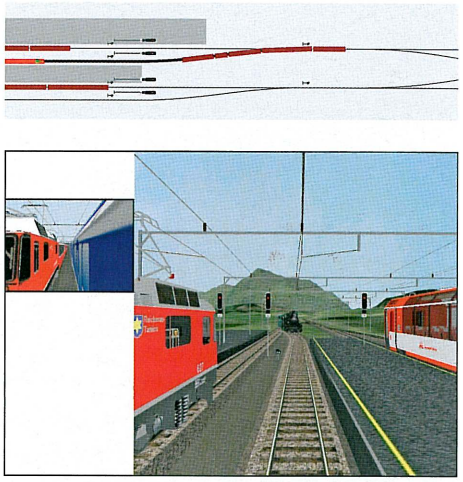
In order to obtain a realistic picture of a train journey from the driver's viewpoint the following components must be actually available or simulated on a computer:

- Driver's desk,
- Vehicle control system, especially interlocks, electrical control circuits, vehicle control unit (VCU),
- Traction elements,
- Auxiliary equipment, brakes,
- Safety equipment,
- Route covered, including fixed safety equipment and catenary,
- Hauled load and running dynamics,
- Environment (view from driver's cab).

Locsim makes all these components available in software form or can integrate relevant hardware parts. The corresponding component of the Railplus simulation system is a driver's desk that includes all control and indicator elements of the participating railways (i.e. the usual switches for starting up, selection of travel direction, tractive and braking effort, but also, for example, rack mode selection or signal activation; and also speedometer, various manometers, tractive effort indicator and a host of signalling lamps). All these elements are connected to a PLC without built-in intelligence that converts the bidirectional signals to or from an RS-232 bus that is linked to the simulation PC.

Vehicle control is implemented entirely on the PC with the exception of the mechanical interlocking between start-up, reversing and driving switches. The traction parameters (determination of tractive effort from switch settings, catenary voltage and speed) as well as auxiliary equipment (for example ventilation, main air reservoir pressure) are likewise simulated on the PC.

The safety equipment covers the usual components (driver's safety device and alertness control) and the following train protection systems whose logic and chronology are simulated on the PC:



View from the driver's cab with rear mirror and track layout of a situation from the RhB training programme with a virtual three-dimensional landscape: track layout at Klosters against the backdrop of the Rigi. The signals can be adjusted by clicking on the track layout. The three other trains can be moved according to a set scenario or manually (photo: BFH).

- Signum and similar train protection equipment in the versions used by SBB and Swiss narrow-gauge railways. For this purpose an acknowledgement switch and the three lights commonly used by the RhB (Rhätische Bahn) are integrated in the driver's desk.
- Track conductor train protection system ZSL 90 of Regionalverkehr Bern – Solothurn (RBS) and the Wynental- und Suhrentalbahn (WSB). The two devices needed in the driver's cab (input and display) are installed in their original form on the driver's desk and are controlled by the PC via a separate RS-232 line and a converter.
- Train protection system ZSI 127 of the Zentralbahn (ZB) and the Bremgarten – Dietikon-Bahn (BDWM). Here again, the two devices needed on the driver's desk (input and display) are installed in their

First trials of the simulation process on a CJ driving trailer. The view of the line is still displayed temporarily on the Notebook screen. This communicates with the driver's desk via a programmable logic controller, the multiple unit control cable and several other connections. The train is in virtual travel mode; note the speedometer (photo: H. Rohrer).

SNTF's Flirt 101 at the Innotrans 2008 (alongside Bombardier tram for Berlin). The simulator aroused considerable interest on the public days despite only being advertised with a simple poster and a short notice in the daily press. Because of the short distances between stations and consequently the possibility of train drivers frequently changing, a Berlin S-Bahn line was loaded instead of the Algiers rapid transit – electrified virtually with 25 kV, otherwise it would not have been possible to switch the train on at all due to undervoltage (photo: H. Rohrer).

original form and are controlled by the PC via a separate RS-232 line and a converter.

Since the primary purpose of the Railplus simulator is to simulate special operational situations, the route is displayed in a virtual three-dimensional landscape. Actual station installations of the participating railways can be strung together along the route in any order and at any distance. The route should therefore not have any steep gradients, and most importantly no tunnels. The line chosen for this was the S-Bahn Zug route which was already available from a previous project. Any signals and indicator boards from the Swiss train running and loading regulations can be placed over the course of this virtual route. Objects such as buildings, vegetation, as well as trains travelling in the opposite direction can be readily installed. Thanks to an interface to the data format of the Microsoft train simulator these objects can be quite easily created with the available editors.

The dynamic running characteristics are determined from the tractive and braking effort, gradient, curve radius and train weight.

Apart from the driver's view ahead, two rear mirrors can also be superimposed simultaneously.

SNTF's Flirt 108 at the Biel/Bienne diploma exhibition. Demonstration of the BLS south ramp (also with 25 kV). With the exception of the electric traction circuits, the train is fully operational, including all display instruments and monitors. A monitor displaying the view of the route is placed in the driver's cab which is blacked out with shutters (photo: BFH).

The programme is operated from the instructor's position via a standard Windows user interface with menus and dialogues. The image visible from the driver's cab (view of the line and rear mirrors), the most important switch settings and instrument displays as well as a track layout are shown on two monitors. All signals and indicators, level crossings, platform installations, the simulated train and all trains running in the opposite direction are shown to scale in this track layout. The positions of fixed signals and the headlights of trains travelling in the opposite direction can be altered to any setting wanted by clicking on them. Adhesion values, catenary voltage, loading of the train line and train laden weight can be varied by means of slide controls. It is also possible to trigger almost any traction unit faults or passenger intervention (such as failure to operate or blocking of equipment, compressed air leakage, stop request, emergency brake request).

The Locsim simulation programme runs on Windows XP and needs a well-equipped standard commercial PC, in other words with high-speed internal bus, rapid hard disk access and a graphic board with accelerator for three-dimensional display. The image processing rate varies between 15 and 40 images per second, depending on the complexity of the situation to be represented (the lower value applies to complex, multi-track railway station installations). During the simulation, all physical parameters such as speed, tractive effort or current and all switching operations and limits such as throttle setting, deadman's pedal or permissible speed are stored in a file. After completion of the simulation run these parameters can be displayed graphically or in a table or exported to other evaluation programmes, for example Excel.

The correct function of the Locsim programme has been verified by various comparative test runs: energy measurements on railcar BDeh 4/4 11 – 17 of the Appenzeller Bahnen (AB), travel time and temperature measurements on railcar Be 4/8 41 – 61 of the RBS, regenerative braking measurements on railcar ABDe 4/4 11 – 16 of the Mittelthurgaubahn (MThB), traction current measurements on railcar Be 8/8 21 – 32 of the Forchbahn (FB), travel time and tractive effort measurements on SBB locomotive Re 460 on the Vevey – Puidoux-Chexbres line [2], and energy and heating measurements on both generations of GTWs (articulated EMUs) of the Thurbo railway company.

Railplus uses the programme for the basic and further training of train drivers. This consists mainly of practicing special operational situations (for example faulty signal lights, faulty train protection system, shunting runs onto the line, occupied station entry tracks, incorrect operation of systems by rail traffic controllers), together with the correct radio and written communications.

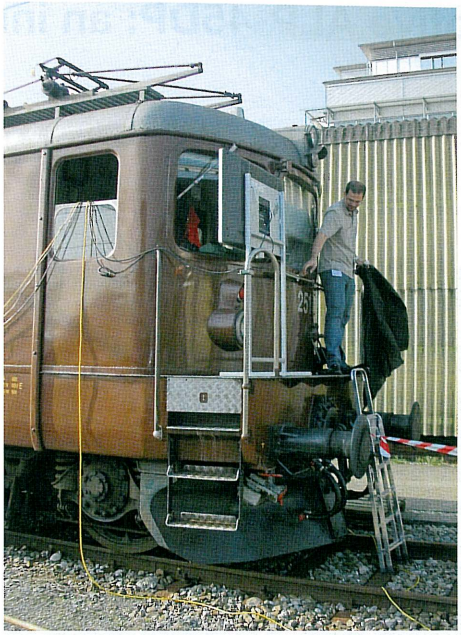
Two years' positive experience with the Railplus simulator has proved the validity of these concepts.

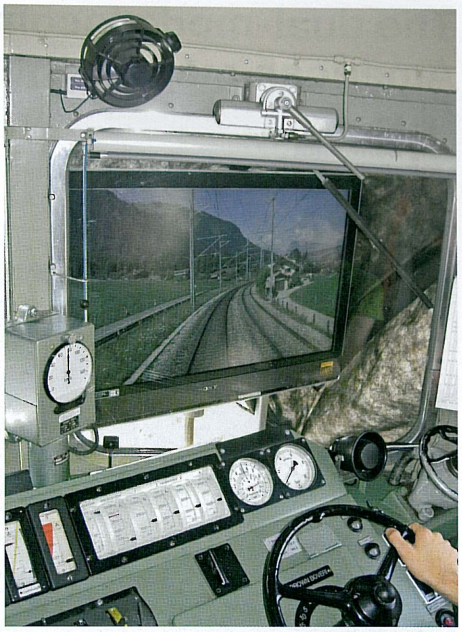
Further developments of the driver's cab simulator

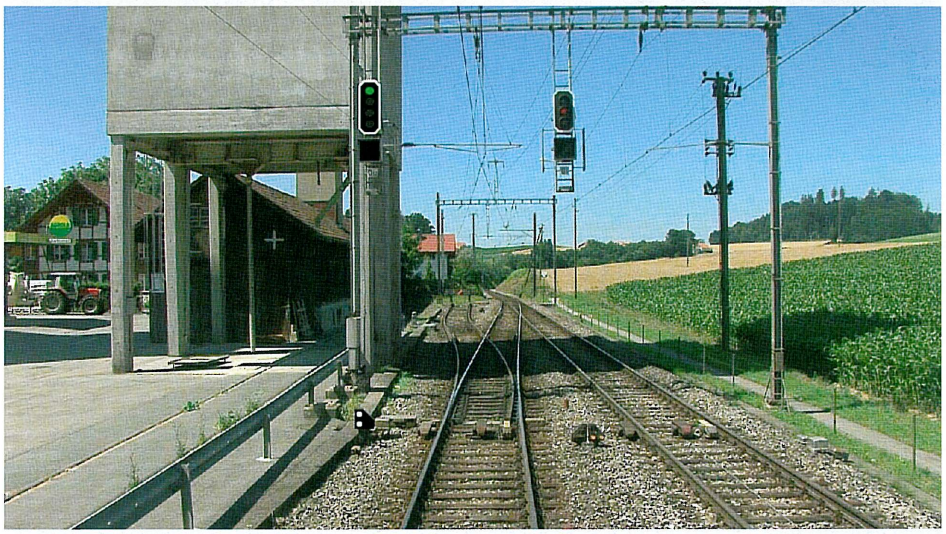
The Railplus simulator will be expanded for a wider area of application in the near future with the installation of the ZUB (Switzerland), PZB 90 (Germany) and ETCS train protection systems.

As an alternative to virtual display, a line can also be projected by means of video film. A new control option created in Locsim allows video films to be played forwards or backwards at any speed. Since the signals during a video journey are naturally usually in open position – which is not always desirable for practising special operational situations – they are overwritten by bitmaps that can be altered by the instructor. Since the video films are used on an individual image basis it is also very simple to display different routes with this method. It is also possible, for example, using the familiar objects from virtual three-dimensional technology, to insert trains travelling in the opposite direction on the film which were not there in reality (when the video was filmed). To display videos the simulation PC must be equipped with a large-capacity hard disk and high-speed access (an hour's video filming is equivalent to more than 20 GB). The image processing rates with present-day computers are about 25 images/second.

A video display is considerably cheaper and faster to implement compared with the virtual three-dimensional world. For example, for the Innotrans railway fair in Berlin in September 2008 the entire Thenia – Alger (Algiers) line of the Algerian State Railways (47 km) was filmed on 15 September 2008, and the edited and synchronised film complete with virtual trains in the opposite direction was already in use on the simulator in Berlin on 23 September. New situations (worksites, etc.) can now be loaded on a simulator in a matter of days.







Top left: Installation of the monitor for displaying the view from the driver's cab on Ae 4/4 251. The monitor and the corresponding front window are to be blacked out with a hood (photo: H. Rohrer).

Top right: The Ae 4/4 in simulation mode: full speed ahead near Frutigen, note the ammeter and the speedometer (photo: J. Bolliger).

Bottom: Video films can be used instead of the virtual three-dimensional image: Rosshäusern (Bern – Neuchâtel) with changeable exit, departure and dwarf signal (photo: BFH).

The precise depiction of actual routes and the good recognisability of locations on the video film also allow train drivers to practise driving with optimized energy consumption.

The multifunctional driver's desk installed in the Railplus simulator container is unsuitable for introducing drivers to new vehicle types since the user interface does not correspond to the original. The obvious answer is therefore to use the driver's desk of the new vehicle itself for the simulation. The vehicle must of course be blocked for this purpose and the power transmission must not be used. If the vehicle control unit and the auxiliary equipment are also operated at the same time, the simulation provides an exact depiction of the vehicle. The view of the line is shown on a large-scale monitor in the darkened driver's cab. Initial trials on vehicles from Railplus and other operators (CJ driving trailer and ASm articulated railcar GTW) showed highly promising results so that in summer 2008 BLS locomotive Ae 4/4 251 and the brand-new Flirt 108 EMU of the Algerian State Railways (SNTF) were adapted accordingly. Both were on show in Biel/Bienne station at the end of August 2008 as part of the diploma exhibition of the Berner Fachhochschule which was followed by the presentation on SNTF's Flirt 101 at the Innotrans 2008 in Berlin. Consequently several railway operators opted for this training method when introducing new traction unit types.

Apart from the actual vehicle, the only hardware needed for a simulator of this type is a PC, a large monitor in the driver's cab and the instructor monitors. If planned at an early stage, the additional parts of the programme can be installed in the VCU (vehicle control unit) already during vehicle development, thus enabling development costs to be kept very low. The great advantage of this type of simulation is that the simulator remains constantly up-to-date, being automatically included whenever the vehicle hard- and software are updated. The simulator is not tied to a particular vehicle; all vehicles in a series can be used flexibly.

By using this method of vehicle simulation together with the video route display system described above, simulators can be implemented at a fraction of the cost of a classic simulator.

Other applications for Locsim

Apart from the simulations of modern railway traction units so far described, Locsim is also suitable for simulating older or historic vehicles. Driver cabs of older vehicle types are used especially for museums and exhibitions. The Bern University of Applied Sciences has equipped the following cabs originating from scrapped rolling stock and simulated the vehicles:

- SNCF's CC 6500 for the Association pour la Préservation du Matériel Ferroviaire Savoyard in Chambéry (inter alia, for the training of drivers for the few preserved locomotives of this type),
- FS' E 636 for the Museo Feralp in Bussoleno near Torino,
- RAe TEE for SBB Historic.

The vehicles are simulated in meticulous detail in all these simulators. All driver's cab elements are used and their effects are simulated (for example, the on-load switch of the CC 6500, voltage system selection on the TEE, traction motor regrouping on the E 636).

Part of the front wall complete with driver's desk was cut out of a scrapped RBS driving trailer and converted into a mobile simulator in the size of a standard pallet. This is fitted out with all equipment such as the ZSL-90 user interface and is used by RBS as a reserve for the container simulator, among other purposes.

As mentioned earlier, Ae 4/4 251 was modified in 2008 for the future BLS museum. A plug allowing access to all necessary signals was installed in the engine room of the locomotive which is still in full working order and frequently used for special trips. Simultaneous acoustics of traction motor ventilation and on-load switch give an authentic driving feel during the virtual journey.

Outlook

Simulators were ordered at the beginning of 2009 for the new multiple units of RBS, RhB and BDWM for deployment on the vehicles themselves (on the basis of the concept tested on the Algerian Flirt). These simulators are implemented jointly with the vehicle manufacturer. Almost all Railplus railways have ordered the display of actual lines by means of video with changeable signals and routes.

Further simulation adapters for historic vehicles and route displays for public simulators are under development for museums and societies.

Literature

[1] Neue Steuerausrüstung für die Doppeltriebwagen der BVZ Zermatt-Bahn. Schweizer Eisenbahn-Revue, 7-8/1999, pp. 328 – 335

[2] Im Regen blieb der Zug stecken – Nächtliche Tests für den Tiefbahnhof Löwenstrasse. Neue Zürcher Zeitung, 6 April 2001, p. 51