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# High-Speed EMU TCMS Design and LCC Technology Research

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ABSTRACT

This paper introduces the high-speed electrical multiple unit (EMU) life cycle, including the design, manufacturing, testing, and maintenance stages. It also presents the train control and monitoring system (TCMS) software development platform, the TCMS testing and verification bench, the EMU driving simulation platform, and the EMU remote data transmittal and maintenance platform. All these platforms and benches combined together make up the EMU life cycle cost (LCC) system. Each platform facilitates EMU LCC management and is an important part of the system.



## 1. Introduction

The high-speed electrical multiple unit (EMU) is one of the most complex terrestrial mass-transportation systems in the world. It consists of dozens of systems and subsystems, hundreds of devices, and thousands of components. These systems and subsystems include traction power and brake, door control, air conditioning, light control, and more. EMU technology combines electrics, electronics, computer science, automation, mechanics, and dynamics. When a new type of EMU is put into service, not only must its design, commissioning, and testing be determined, but aspects such as driver training, operation management, maintenance periods, and tools must also be considered.

After several years of research, development, and application, the China Academy of Railway Sciences (CARS) has built an EMU life cycle cost (LCC) management system based on digital and simulation technology. The EMU LCC management system involves EMU design, developing, testing, training, operation, and maintenance phases, thus incorporating almost the whole EMU life cycle. This paper introduces the LCC management system from the point of view of the train control and monitoring system (TCMS) of the EMU at different stages, including the design, developing, testing, verification, and maintenance stages; it also discusses related technologies, tools, and platforms.

TCMS is a train-borne distributed control system. It comprises computer devices and software, human-machine interfaces (HMIs), digital and analog input/output (I/O) capability, as well as the data networks required to connect all these components together in a secure and fault-resistant manner. TCMS is the standard control, communication, and train management system for all vehicle platforms and applications, ranging from trams, metros, passenger coaches, and people movers to multiple-car trains, high-performance locomotives, and high-speed trains. The precise TCMS architecture deployed varies depending on operational requirements and the market segment, but the purpose and benefits of TCMS are common across all architectures.

The TCMS software development platform is used from the earliest stages of the conception and realization of a new type of EMU. TCMS is the brain of an EMU because it controls and monitors all onboard subsystems and devices. Thus, starting from the

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initial design phase, EMU systems, subsystems, interfaces, and the control logic functions between each system must be considered. Diagnostics functions and maintenance issues must also be included, such as monitoring the operating status of all the subsystem devices, and defining all the necessary diagnosis codes for each fault of TCMS and of the subsystems. Reliability, availability, maintainability, and safety (RAMS) parameters are considered as well, in order to build a flexible, convenient, and easy-to-use onboard control and monitoring system from the initial phase.

The TCMS testing and verification bench is also used during EMU LCC management. In order to implement the manufacture of a new type of EMU, several subsystems from different suppliers are integrated. For this reason, subsystems' interfaces and control functions—which must satisfy the agreed-upon requirements between the TCMS integrator and the subsystem providers—must be tested and verified. The TCMS integration tests include communication and signal interface tests, control logic function tests, and a diagnostic function test. The use of a TCMS testing bench is also advantageous for EMU LCC management because it shortens the EMU test time and cost.

The EMU driving simulation platform is built on the base of the TCMS software development platform and the TCMS testing and verification bench. It combines visual 3D technology with EMU system function simulation models. The driver desk, operation handles, instruments, power line, and track circumstance are built by exploiting a 3D modeling technology. Driving events, conditions, and track data are inputted into the 3D EMU mechanical model and into the EMU function simulation model. The output data of the EMU function simulation model are then sent back to the 3D mechanical model in order to display, for example, the speed responses of the EMU. The EMU driving simulation platform can also be used for the operation and maintenance training of drivers and maintenance staff.

The EMU remote data transmittal and maintenance platform is used by maintenance staff in depots or workshops in order to monitor the EMU operation states from a website and then assign maintenance work on the EMUs according to operation and fault conditions. With wireless transmission devices (WTDs) installed on the EMUs, it is possible to monitor the operation statuses of onboard systems and devices and remotely download fault messages. The maintenance staff utilizes these kinds of information to assign maintenance tasks and prepare the necessary maintenance tools, consumables, and spare parts before an EMU's return to the depot.

The TCMS software development platform, TCMS testing and verification bench, EMU driving simulation platform, and EMU remote data transmittal and maintenance platform constitute the main structure of the EMU LCC management system. With this system, system engineers can focus on LCC management from the early design phase to the operation phase, and even into the maintenance stage. It is also helpful for driver and maintenance staff training. During the operation stage, the system also benefits maintenance work in the depot. In addition, the depot application feedbacks and maintenance experiences may be inputted into the EMU remote data transmittal and maintenance platform in order to continuously improve EMU performance, subsystem control, and diagnostic functions.

## 2. The TCMS software development platform and the TCMS testing and verification bench

Together, the EMU TCMS software development platform and the TCMS testing and verification bench are a unified platform for TCMS software design and verification and for hardware and software integration testing. The platform development includes the environment for the development of visual application software, for the integration of embedded applications and the real-time operating system, for the development of network control units interface driver packages, and for the synchronized development and collaborative testing of the design and verification software.

### *2.1. The TCMS software development platform*

TCMS is an onboard system built with the purpose of controlling and monitoring almost all the train equipment and functional processes. TCMS applications include scalable hardware models and software function blocks, which comply with the vehicle builders' requirements. Based on the control and monitoring architecture, TCMS centralizes all the information related to the operating status of all the so-called "intelligent" train equipment.

The TCMS software development platform has the following characteristics:

- It provides the hardware driver for central processing unit (CPU) and I/O interfaces.
- It provides function block diagram (FBD) libraries.
- It provides the diagnostic block function and data storage function.
- It automatically compiles, links, and generates the executable code.
- It provides online monitoring tools for commissioning and investigation.

Fig. 1 shows the structure of the TCMS software development platform.

**Structure and application**

The TCMS software development platform relies on the basic software ControlBuild, a systems engineering software tool. ControlBuild supports the IEC 61131-3 (sequential function chart (SFC), ladder diagram (LD), FBD, and structured text (ST)) and electrical schematic languages. However, it is insufficient for the development of TCMS application software, so the abovementioned functional requirements must be implemented [1].

Object hardware driver development includes two main parts. The first part is the development of the driver for I/O cards, with the cards being divided into digital and analog according to the signal type. The second part is the development of the driver for the communication interface cards. Of course, most EMUs use the IEC 61375-1 train communication network (TCN) technology, which consists of the multifunction vehicle bus (MVB) normally used for intra-vehicle communication and the wired train bus (WTB) for train-wide connection and information exchange. The communication interface drivers make it possible to send and receive MVB and WTB process data and message data telegrams.

An FBD library contains all the basic function blocks and libraries for arithmetic, control, logic, TCN, and so forth. For example, the pantograph raise control logic checks several conditions as follows: When the driver's key is inserted, the main circuit breaker is switched off, the train traction circuit is not connected to earth, the air pressure is above the threshold, and no condition for lowering the pantograph exists, all these conditions are used in AND logic by the application software in order to allow the command—received from the pantograph toggle switch—to raise the pantograph. In this case, the actuation signal will be output. In general, the development of EMU application software requires many arithmetic, control, logic, and communication data-exchange blocks and models.

Diagnostic and data storage blocks and the data storage function realize diagnostic functions and allow the capture and recording of event data, in order to manage, store, and process the fault codes, reporting their occurrence and recover time with