



# China on the Fast Track

Chinese railway equipment manufacturer uses dSPACE HIL to speed up their Traction Control Unit (TCU) development.





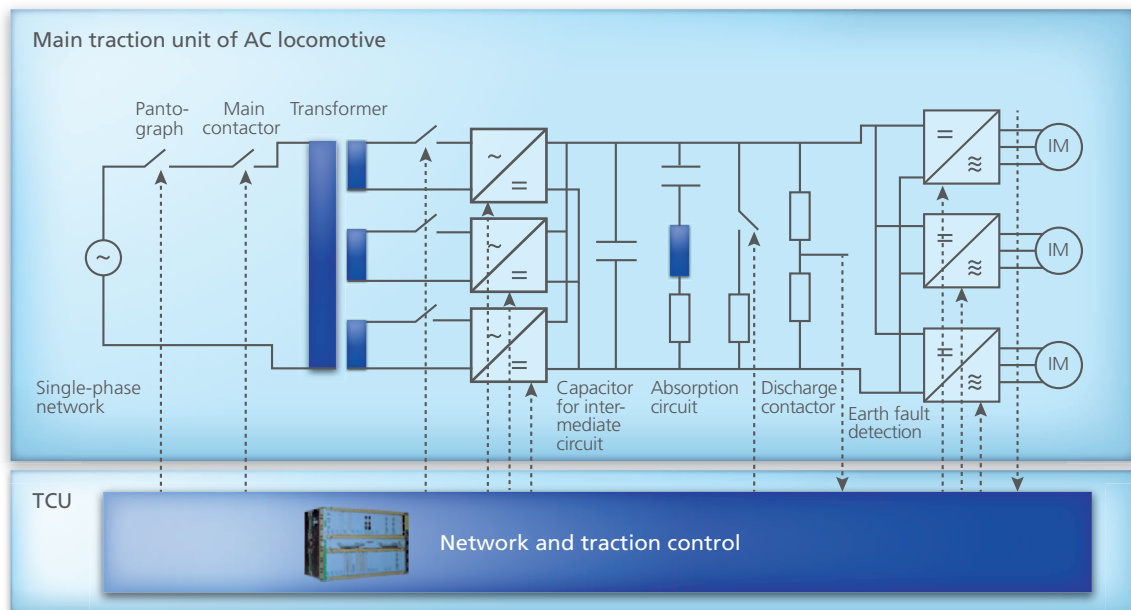


Figure 1: TCU and main traction unit of AC electric locomotives.

### Background

China, with its largest population and second largest economy in the world, is revolutionizing its railway, its once obsolete, low-efficient major transportation infrastructure. After only 5 years it has successfully updated the old railway to a very modern and comprehensive system, ranging from metro lines high-speed trains like the TGV and ICE in Europe. This trend also opens up huge opportunities for local railway equipment suppliers. Benefiting from large sum of state subventions, the Dalian Electric Traction R&D Center, a subordinate company of the China

Northern Railway (CNR) Group, has recently begun to develop Traction Control Units (TCUs) for AC electric locomotives. In this project, a very critical aspect is the development cycle. And since everything is started from scratch, almost all functions including various diagnosis functions must be thoroughly evaluated and tested; there is no time to set up a full-scale power test bench. Under these circumstances, the Dalian Electric Traction R&D Center decided to use the hardware-in-loop (HIL) approach, well established in the automotive industry, to test their TCU software and hardware.

### What is TCU?

TCU is short for Traction Control Unit and is responsible for the optimal operation of the main traction unit of AC electric locomotives.

The main traction unit draws power from an AC overhead line with fixed frequency through pantographs and converts the power to variable frequency AC power to drive the traction electric motors on the bogie (figure 1).

A typical TCU is composed of one part for the line and one for the motor. The line side controls the line's power factor and stabilizes the DC link voltage, the motor side controls the

“With a dSPACE DS5203 FPGA Board, we can conveniently run our own simulation model at 100 ns to match the real-time simulation data perfectly to the experimental results acquired on the power test bench.”

Congqian Xu, staff engineer of HIL team, CNR



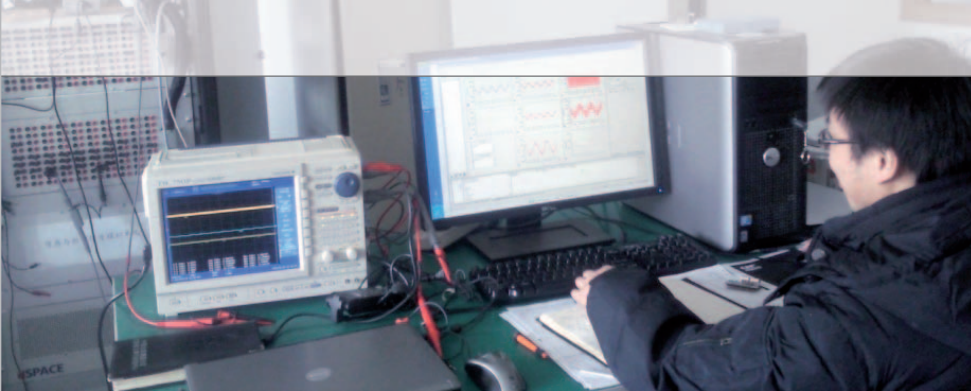


Figure 2: The HIL rig contains a TCU under test, signal conditioning unit and dSPACE modular hardware (DS1005, DS5203, DS5001, DS5101 and DS2302).

inverter and traction motors to achieve the required torque and speed.

### Why the HIL Approach?

As in the automotive industry, HIL simulators quickly established themselves as very efficient, indispensable tools in the development and verification of locomotive controller software. Major international players such as Bombardier, Alstom and ABB use HIL systems to develop and test the complex TCU software. After carefully studying the experience

of international competitors and the automotive industry, the Dalian Electric Traction R&D Center of CNR included HIL simulators in their entire development process in order to detect software and hardware bugs in the early stage of development (figure 2).

Unlike chemical processes in the combustion engine, the electromagnetic process in the electric traction unit can be accurately simulated thanks to a precise set of analytical equations. So it is possible to include HIL simulator in the early

stage of TCU development to verify the controller functions, like evaluating the effect of different modulation methods on motor torque in different working conditions. Since power devices such as IGBTs (Insulated-gate bipolar transistor) are implemented in the model, the engineers don't have to worry about high voltage equipment being harmed by faulty gating signals.

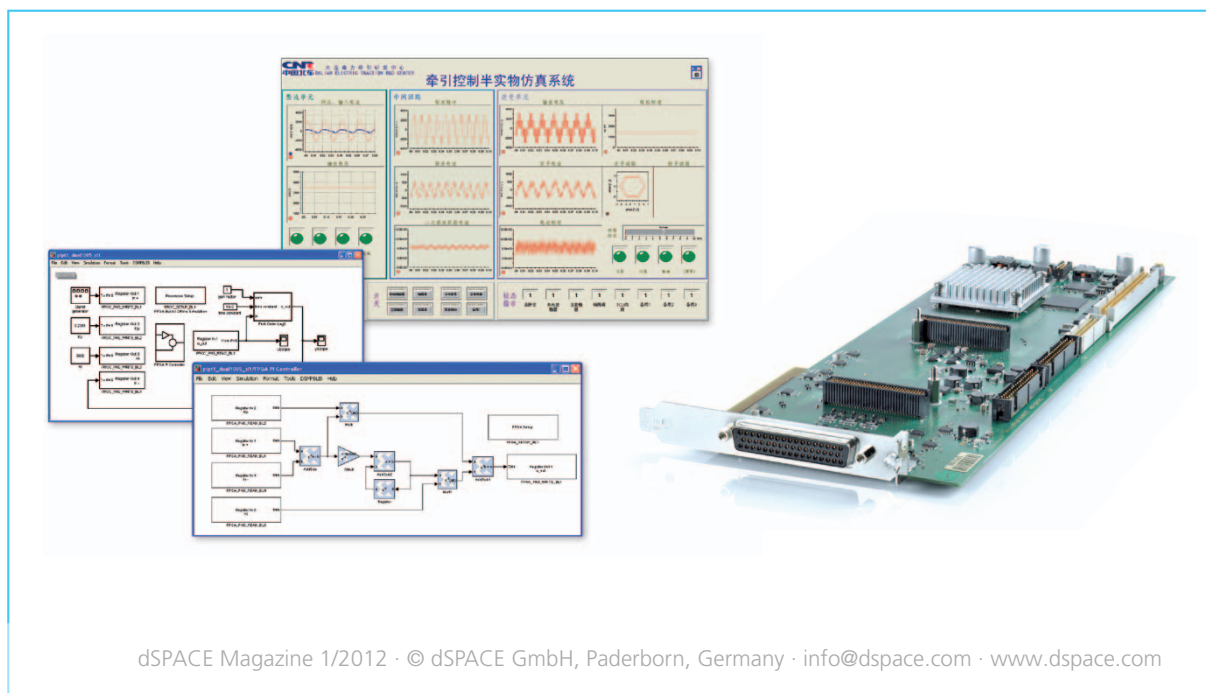
### The Challenges Met

In simulating power electronic systems and drive systems like an elec-

“We decided to use a dSPACE HIL simulator as it already has proven its value in the broad range of the automotive industry.”

*Xiangdong Che, head of the electric traction department, CNR*

Figure 3: The plant model is graphically implemented in Simulink® with RTI FPGA Blockset and Xilinx® System Generator blocks.



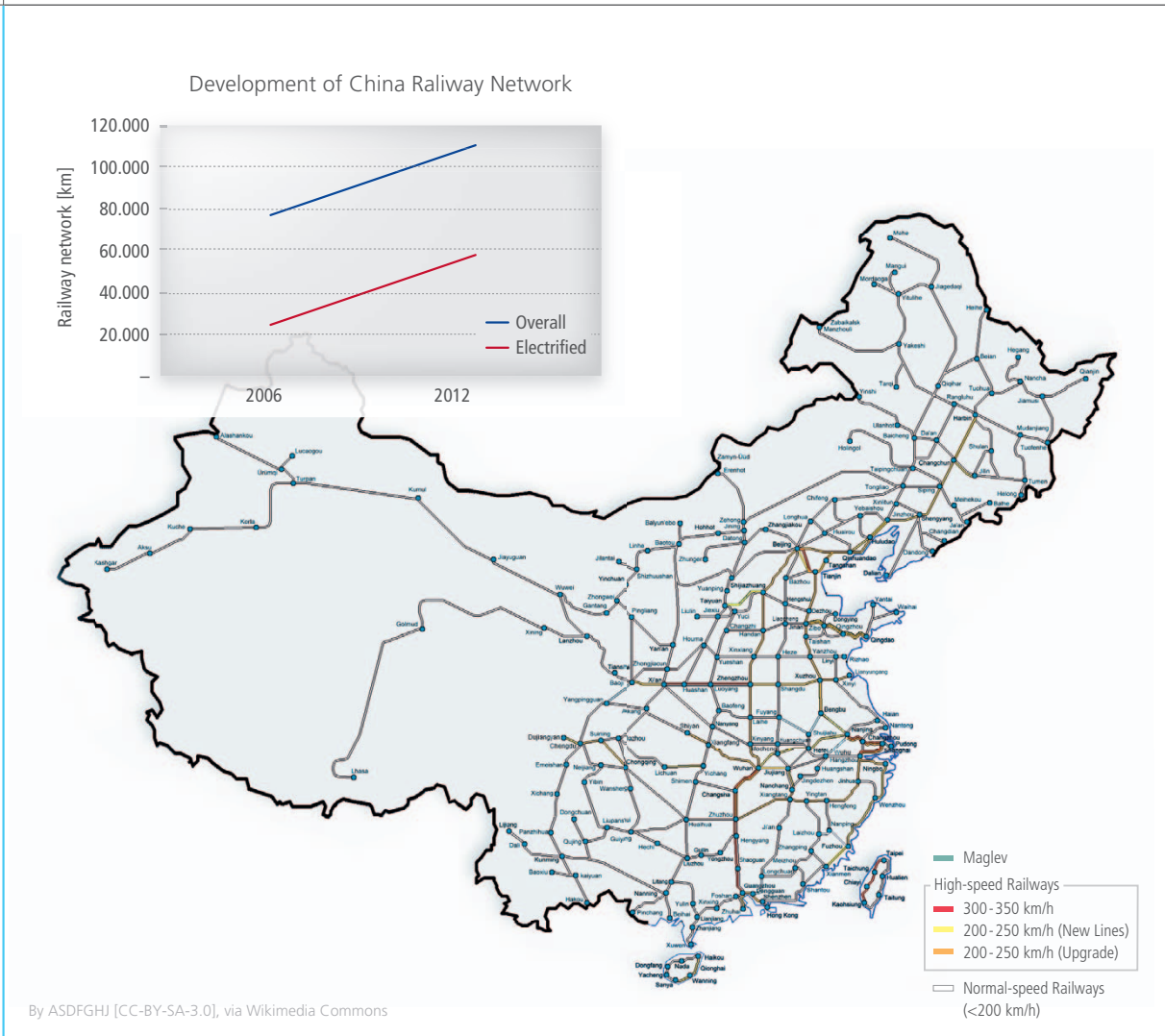


Figure 4: Over the last 6 years, the Chinese railway network has more than doubled its electrified railways.

“A further advantage of a dSPACE simulator in locomotives is that we could utilize it in the very early stage of development, not only in the integration test.”

*Xiangdong Che, head of the electric traction department, CNR*

tric locomotive traction unit, the most challenging problem is the sampling of high-frequency power switch gate signals. If, for example, the inverter and traction electric machine is to be simulated on the real-time computer, the sampling error of gating signals will accumulate in the calculation of machine

fluxes, leading to very poor simulation results. This error occurs at each gating signal transition and gets worse when the ratio of sample time to the switching period of gating signals becomes higher. Based on experience, a very satisfactory simulation result for an HIL test would be achieved with the ratio of 1/100.

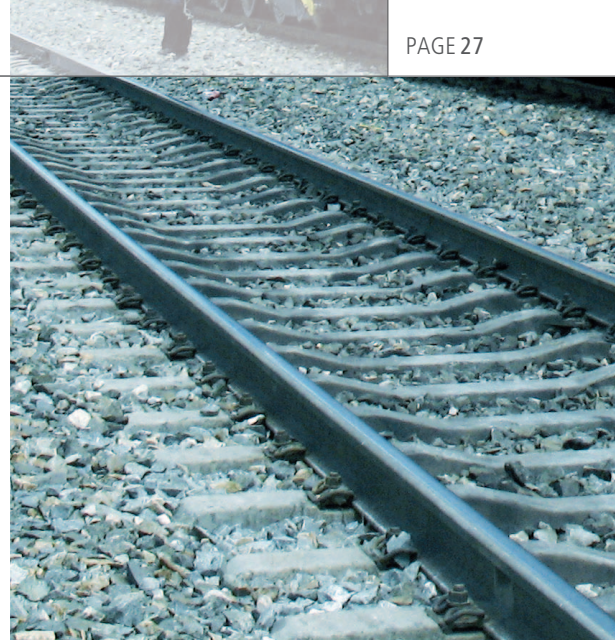
This means the time step of real-time simulator should be 1  $\mu$ s in order to sample a 10 kHz gating signal, which is fairly common in the highly dynamic control of electric machines.

This time step requirement poses a great challenge to HIL vendors because it is impossible to run simulation models on any CPUs with such a small time step. Even parallel computing cannot solve this problem with current technology. So recently, FPGA-based solutions were brought forward to counter this problem, and this achieved very good results. However, in most of the commercial solutions the reconfiguration of the computing hardware must be done

by the HIL vendors and not all the customers are comfortable with the hardware description language VHDL or Verilog coding, let alone hardware synthesis technologies. The newly released dSPACE DS5203 FPGA Board offers a good opportunity to solve both problems elegantly. With the help of dSPACE RTI FPGA Programming Blockset and Xilinx System Generator, CNR could conveniently build the simulation model in Simulink, compile and synthesize it in bit streams and then download them in the board, all automatically. The FPGA reconfiguration could be done in a graphical environment without any knowledge of VHDL or Verilog coding. The Electric Traction R&D Center utilized this feature and ported their original model to the FPGA model running on DS5203 board without much effort (figure 3). The powerful FPGA device Xilinx Virtex 5 on the DS5203 provides the possibility to implement very large, complex models on the FPGA device. After some optimization, the Electric Traction R&D Center of CNR

successfully implemented the complete main traction unit, including 3 4QC converters, 1 DC link, and 3 inverters and 3 traction electric machines on a single DS5203 board. With the help of the FPGA's parallel computing feature, the main electric traction unit can be executed at a 100 ns time step, yielding very accurate real-time simulation results. ■

*Dr. Xizheng Guo  
Congqian Xu  
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## Result and future plans

Since the dSPACE HIL simulator is used at a very early development stage and much less power test bench involvement is needed for algorithm verification, the TCU development cycle has been shortened dramatically: TCU software and hardware testing under various working conditions can be now easily implemented without the danger of harming power devices or machines.

Encouraged by the current success in TCU development, the Electric Traction R&D Center plans to purchase more DS5203 boards to test the TCUs of larger-scale railway vehicles. It is also under discussion to purchase several full-size HILs to implement a full-scale virtual train to test networked electronic controllers for the high-speed CHR trains.

### *Congqian Xu*

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### *Dr. Xizheng Guo*

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