Tata Motors Develops Engine Management System for Tata Nano, the World's Least Expensive Car

The Tata Nano.

The Challenge

Design a brand-new engine management system for the Tata Nano and meet strict cost and schedule constraints

The Solution

Use MathWorks tools for Model-Based Design to model, simulate, and generate code for a prototype control system

The Results

- Two costly sensors eliminated
- Validation cycle time reduced from weeks to hours
- Prototype designed and requirements proved before supplier selection

Heralded as the world's most affordable automobile, at launch, the Tata Nano costs about $2500. Equipped with a 624 cc two-cylinder engine, the Nano seats four and is capable of maintaining a speed of 105 kph (65 mph). It has the highest fuel efficiency (23 km/l, or 54 mpg) and lowest CO_2 emissions (101 gm/km) of any Indian automobile.

To meet ambitious cost and efficiency goals set for the Nano, Tata engineers designed a completely new engine management system (EMS). They cut development time and product costs by using Model-Based Design.

"Model-Based Design enabled us to rapidly develop a prototype engine and EMS, evaluate design alternatives, and refine requirements for the production hardware and software," says S Govindarajan, deputy general manager of the Advanced Engineering Group at Tata Motors. "Based on our success with the Nano EMS, we are now using the MathWorks tool chain on many projects."

The Challenge

Because the Nano was unlike any other car, both the engine and components had to be designed and developed from the ground up. As a result, when the project started, the EMS requirements changed frequently.

Safety, emissions, comfort, and drivability goals had to be achieved at the lowest possible cost. Engineers needed to identify and eliminate unnecessary components, such as those that could be replaced with software functions. At the same time, they needed to ensure that the software required minimal memory and executed quickly.

In addition to product cost, development time was another challenge. Before the Nano, Tata Motors needed to wait for the vendor to supply a working EMS before they could fire the engine. "For the Nano, we felt that de-contenting an existing EMS for the India market would not meet the cost goal for the Nano," says Prasanta Sarkar, assistant general manager at Tata Technologies. "On the other hand, iterating with the supplier on a completely new design would take too long. Therefore, we had to bring the initial development in-house."

The Solution

Tata Motors adopted Model-Based Design because this approach enables engineers to explore design options, quickly prototype, and refine control strategies—critical capabilities given the schedule and cost constraints. Not having developed an entire EMS in-house, Tata engineers wanted to use an established tool chain to reduce ramp-up time. They selected MATLAB®, Simulink®, Stateflow®, and Simulink Coder™.

Before the prototype engine was ready, Tata Motors engineers modeled the control system, including start, idle, partial load, and full load modes of operation.

To perform closed-loop simulations, the team integrated the controller model with a Simulink engine model for software-in-the-loop (SIL) and hardware-in-the-loop (HIL) testing. These tests enabled the team to verify normal operation of the controller as well as its ability to handle fault conditions, such as shorting power and ground lines to the electronic control unit (ECU), short and

"Prototyping with Model-Based Design proved essential. With an integrated platform for modeling, simulation, and testing, we could rapidly make changes and predict how the whole system would react before it was built. This early insight shaped the design of the controller, engine, and Nano itself." —S Govindarajan, Tata Motors

open circuits for sensors and actuators, and unexpected resets of the ECU.

Simulations and HIL tests enabled Tata Motors to evaluate engine capacity, torque output, and the electrical architecture. These early assessments were vital because the team had no benchmark vehicle to verify design feasibility.

Following HIL tests, the team deployed the control algorithms to its fleet of prototype Nanos using an on-target rapid prototyping ECU. The engineers performed rapid iterations in which they refined the Simulink model to resolve issues revealed by testing before regenerating the software.

After verifying the requirements in prototype Nanos, Tata Motors provided detailed requirements for the EMS and selected the supplier. Tata Motors and the supplier jointly created the production version.

The production EMS design surpasses all key goals for safety, cost, and fuel efficiency, and meets India's stringent Bharat Stage IV emissions standards. Based on the success of the Nano project, Tata engineers have expanded the scope of embedded software development using Embedded Coder™ for production code generation.

The Results

Two costly sensors eliminated. "Through our simulations in Simulink, we identified two sensors that we could replace with embedded software functionality," says Sarkar. "We replaced the CAM sensor and the knock sensor with software functions and calibrations, saving the cost of the sensors and their wiring harnesses."

Validation cycle time reduced from weeks to hours. "When we began the software design there were many unknowns, so we needed numerous design iterations," says Sarkar. "We accelerated this process by modeling and simulating in Simulink and generating code with Simulink Coder. Validation of each software release, which can take weeks with a conventional approach, was completed in about half a day."

Prototype designed and requirements proved before supplier selection. "Model-Based Design enabled us to develop the complete EMS prototype ourselves," notes Govindarajan. "Our development skills and the knowledge we gained about the EMS helped Tata Motors negotiate and collaborate more effectively with our suppliers. By demonstrating a prototype working on a Nano with no problems, we reduced the risk for both Tata and our supplier."

Industry

- Automotive

Application Areas

- System design and simulation
- Rapid prototyping
- Embedded systems
- Control systems

Products Used

- MATLAB®
- Simulink®
- MATLAB Coder™
- Simulink Coder™
- Stateflow®

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