

GM Standardizes on Model-Based Design for Hybrid Powertrain Development

General Motors' Two-Mode Hybrid powertrain optimizes fuel efficiency for a range of driving conditions, including stop-and-go city driving, rapid acceleration, and steady-state highway driving. Widely recognized as a major advance in hybrid technology, the Two-Mode Hybrid combines a conventional engine with two 60 kW electric motors integrated into an automatic transmission with three planetary gear sets.

GM engineers used Model-Based Design to develop the Two-Mode Hybrid powertrain control system, which is now in production in GMC Sierra Hybrid, GMC Yukon Hybrid, Chevy Tahoe Hybrid, Chevy Silverado Hybrid, and Cadillac Escalade Hybrid vehicles and will be adapted for use in the Chevy Volt, GM's extended-range electric vehicle.

"By enabling us to work at a higher level of abstraction, verify our designs through early system simulation, and automatically generate production code from our models, Model-Based Design gave us the flexibility to try new approaches and control strategies virtually, rapidly make changes, and eliminate translation errors common in hand-coding," says Greg Hubbard, senior manager, Hybrid and Electric Drive Controls, GM.

THE CHALLENGE

GM wanted vehicles with the Two-Mode Hybrid powertrain in production within four years. For a conventional powertrain project, this timing would be typical, because the engineering team could start with an existing design. Early Two-Mode Hybrid technology had been developed by GM and Allison for use in transit buses now in operation in over 100 cities, but because the technology needed to be "leaner and greener" for passenger car



Badge for GM's Two-Mode Hybrid powertrain, which is used in vehicles across several product lines.

and truck applications, the team had to start from scratch. "Creating well over a million lines of code on a compressed schedule, while ensuring that the control system meets GM's high quality standards and complying with all legislative regulations and safety standards, was a tremendous challenge," says Hubbard.

GM engineers also had to optimize the design for several competing objectives, including fuel economy, responsiveness, and driver comfort, while keeping the design flexible enough to use across a range of vehicles. To do that, GM engineers had to ensure that several complex systems worked together to optimize performance. "Integrating the engine, transmission, electric motors, and battery with the power management strategy is the key to hybrid system design," explains Kent Helfrich, director of Powertrain Software Engineering at GM. "These systems are too complex to build separately and integrate in a final step."

In addition, GM engineers needed to verify their designs before committing them to hardware.

THE SOLUTION

GM used MathWorks tools and Model-Based Design to develop system models, verify

THE CHALLENGE

Develop new hybrid powertrain technology for GM vehicles

THE SOLUTION

Standardize on MathWorks tools and Model-Based Design for control systems design and production code generation

THE RESULTS

- Aggressive delivery date met
- Worldwide collaboration and communication of design concepts enabled
- Designs reused across product lines

designs using simulation, and generate production code for the Two-Mode Hybrid powertrain control system. This approach enabled GM engineers to explore multiple strategies, accelerate design iterations, minimize prototypes and rework, and verify the control system before hardware was available.

Using MATLAB®, Simulink®, and Stateflow®, GM engineers designed the control system architecture and modeled all the control and diagnostic functions, including hybrid operating strategy, engine start-stop, active damping, shift execution, and propulsion safety.

At the same time, they created detailed plant models for all relevant physical systems, such as the engine, electric motors, battery, hybrid transmission, and vehicle dynamics. Running closed-loop simulations with the plant model, they verified the control system using standard city and highway driving fuel economy tests.

After generating production code for the engine, transmission, and hybrid energy management ECUs using Real-Time Workshop Embedded Coder™, they further verified the control systems using Real-Time Workshop® and hardware-in-the-loop (HIL) simulators with the plant models and test cases from the non-real-time verification phase. Comparing the results of these tests enabled the engineers to identify ECU integration issues.

When the hybrid powertrain hardware became available, the team was able to move quickly from HIL to prototype vehicles for confirmation testing.

The Two-Mode Hybrid powertrain has won several awards, including Technology of the Year from *Automobile* magazine and Green Car of the Year from *Green Car Journal*.

“The Two-Mode Hybrid powertrain took Model-Based Design to a new level within GM. This project provided the confidence and experience we needed to apply MathWorks tools for Model-Based Design on other large-scale global engineering programs.”

Kent Helfrich, GM

THE RESULTS

■ **Aggressive delivery date met.** “Just nine months after we started the project, we had our first prototype vehicle running,” says Hubbard. “We would not have been able to do that without MathWorks tools. The software enabled us to complete significant amounts of design work before hardware was available.”

■ **Worldwide collaboration and communication enabled.** GM engineers in Michigan shared Simulink models with GM engineers in Europe and Asia. As a result, teams around the world could work on different aspects of the design—such as control strategies, software design, and physics problems—at the same time, leveraging each engineer’s strengths and eliminating integration issues. “The Simulink models served as a single source of truth for teams around the world,” says Hubbard.

■ **Designs reused across product lines.** “We are reusing the controller architecture for additional vehicles that are in production, including the GMC Sierra and Chevy Silverado, as well as the forthcoming Chevy Volt,” says Hubbard. “The control system design for the Chevy Volt progressed quickly because we were able to reuse the controller architecture.”

Learn more about General Motors:
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APPLICATION AREAS

- Model-Based Design
- Automotive
- Code generation
- Event-based modeling
- Verification, validation, and testing

PRODUCTS USED

- MATLAB®
- Simulink®
- Stateflow®
- Real-Time Workshop Embedded Coder™
- Real-Time Workshop®

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