dSPACE Tools

for Rapid Development of UWAFT EcoCAR

The University of Waterloo Alternative Fuels Team (UWAFT) is always looking for ways to bring their work to a higher level. So when they set out to build a vehicle for the EcoCAR Challenge, not only did they choose a complex powertrain, but they also welcomed the chance to explore new methods and technology that would significantly change the vehicle development process.

In a Fuel Cell Plug-In Hybrid Electric Vehicle like the one being built at the University of Waterloo (UW), the control code written to synchronize component operation is just as important as the physical parts themselves. The supervisory controller acts as the "brain" of the vehicle, interpreting what each component tells it and relaying instructions back to the powertrain components to ensure they are functioning properly. If the algorithms and code are not correctly designed or implemented, the vehicle will not be able to monitor faults and respond in a reliable and safe manner. So the students at UW were faced with the question every designer asks: how do you speed up the development process without compromising safety and reliability?

Model-Based Design, DFMEA and HIL

Advances in model-based design (MBD) fuelled by designer's demand for rapid development methods in the automotive industry, made MBD an obvious approach for UWAFT to use as part of its work in the EcoCAR Challenge. This approach was implemented in order to design UWAFT's powertrain control strategy. Organized around the logical transition from software models to hardware systems, the team stepped through three progressive stages of the MBD approach.

Step 1: Software-Based Programming of Control Code

Initially the team used Argonne National Laboratory's PSAT software for high-level simulation using manufacturer-supplied specifications to define component models. The program includes a set of simplified component models constructed in Simulink. At this point, control strategy development could begin. Using the component models as a software place holder for the vehicles' components, physical connections were replaced with Simulink® signals for the purpose of testing control algorithms. This would confirm that the strategy behaved as expected. The next stage would be the Design Failure Mode Effects Analysis (DFMEA), where system vulnerabilities are identified by inserting faults that could occur on the vehicle and then acting on the faults by either mitigating or eliminating undesired effects.

dSPACE Hardware-In-the-Loop Simulator

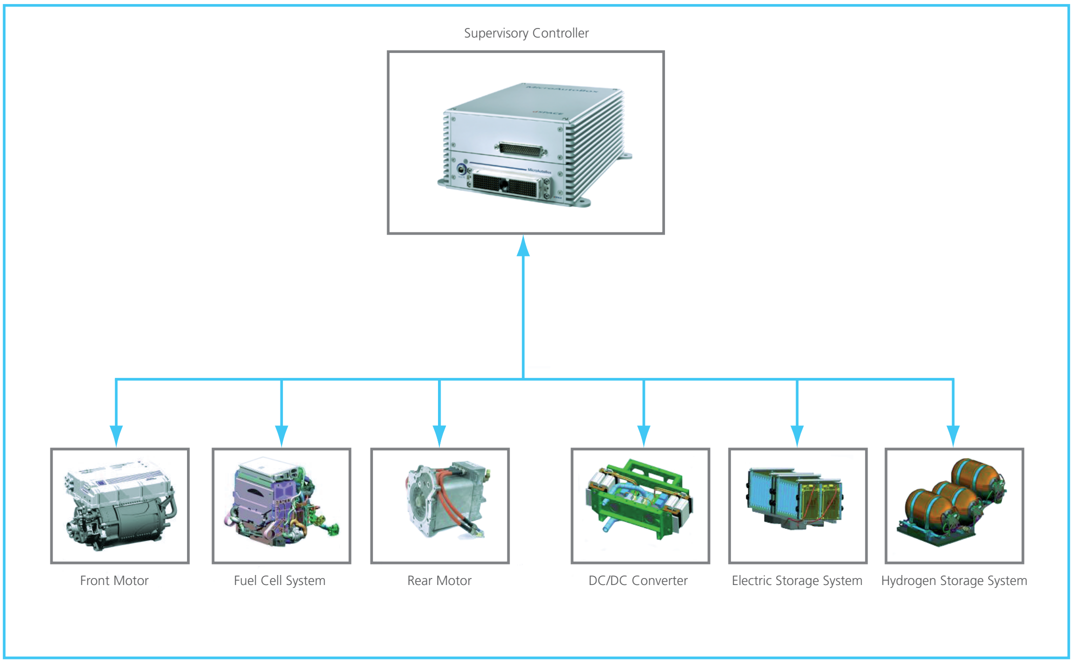
Since this software-based validation process is based on a finite set of failure modes, it would only partially confirm the robustness of the control system. Additionally, this method does not identify the physical untested issues in the actual vehicle, such as malfunctioning sensors on the vehicle or loss of communication with components. To work through these issues, the software-based process would require the controller to be integrated into a physical setup with the actual vehicle. Implementation of the controller directly on the actual vehicle is an option, but this approach is time-consuming and it would have made the vehicle unavailable for other development work by UWAFT's mechanical and control teams.

Another concern with implementing the controller onto the vehicle is the risk of harming expensive and important vehicle components during fault testing. The team needed a tool that, ideally, could simulate the vehicle to allow for parallel development of the control and mechanical systems and prevent a destructive development process.

Step 2: Hardware-in-the-Loop Simulation

As an EcoCAR competition sponsor, dSPACE Inc. generously provided hardware and software solutions to student teams to assist in the development of their powertrain control system. In terms of hardware, dSPACE provided

dSPACE MicroAutoBox



its MicroAutoBox and its hardware-in-the-loop simulator which gave the students the ability to simulate various powertrain failures without damaging real-world components. dSPACE also provided fault insertion and interface software, and mentorship from experienced software engineers to assist students in vehicle development.

With dSPACE's support UWAFT was able to develop and implement its control system strategy with relative ease. This ease of control strategy implementation was made possible since dSPACE software is based in the Simulink environment and is closely compatible with PSAT (program used in Step 1 described above). Using a dSPACE MicroAutoBox to fill the role of the supervisory controller, the team had a powerful processing platform onto which it could install its customized control code. This system would host the code containing algorithms that control the operation of every major component in the vehicle. The other vital piece of hardware received was a dSPACE Simulator Mid-Size. This system enabled both real-time simulation and fault insertion capabilities, and it was used to simulate the physical connections that the controller would expect from the car. When combined with the dSPACE ControlDesk® and AutomationDesk® software packages it allowed for complete control and testing of the controller. Most importantly was its ability to simulate more serious powertrain failures. For example, controller response to battery overheating, loss of motor control, or CAN bus failure can be tested without risk.

Step 3: Validation of Control Code with Actual Vehicle Components

After UWAFT's vehicle control strategy passed all the required tests in the simulated environment, the MicroAutoBox was ready to be installed and tested in the actual vehicle.

Learning Experience for Student Engineers

Using dSPACE tools to identify, detect, and protect control systems against failures greatly sped up the development process and freed up time for mechanical work to be done on the vehicle at the same time. Using HIL tools in combination with failure insertion for FMEA, the team identified potential vehicle system failures and their corresponding solutions.

The learning curve for UWAFT's engineering students was far less steep with the support of dSPACE. And, since dSPACE tools are compatible with programming environments used earlier in the EcoCAR competition, the control systems development process for the UWAFT engineers was a smooth and progressive one.

Another important benefit of using dSPACE tools was the ability to decouple controls development from the mechanical work being done on the car. Simulating the signals that the controller would expect from an actual vehicle allowed code to be tested in an independent environment while freeing up the vehicle for any mechanical work.