

Automotive Research Lab at Penn State Gives Students Practical Hardware-in-the-Loop Experience

In a graduate-level course at Penn State, engineering students use hardware-in-the-loop (HIL) methodologies to study electric, hybrid-electric, and fuel cell vehicle technology.

“To our knowledge, this is the only course in the country focused on HIL for advanced vehicles,” says Dr. Sean Brennan, assistant professor of mechanical engineering, who co-teaches the course with Dr. Joel Anstrom, director of the Graduate Automotive Technology Education (GATE) Program at Penn State.

Advanced Vehicle Hardware-in-the-Loop Methods is part of a comprehensive, Department of Energy funded, GATE curriculum. Working with advanced powertrain components in Penn State’s HIL network — which was developed with MathWorks™ software — students use Simulink® and xPC Target™ to complete the course labs.

“MathWorks tools enable us to integrate research and teaching,” Dr. Brennan says. “Implicit in that is rapid turnaround — the tools enable my colleagues and me to set up lab hardware in minutes, while our students use them to quickly apply high-level concepts, visualize results, and control real hardware.”

THE CHALLENGE

Penn State’s HIL network links fuel cells, batteries, ultracapacitors, electric drive motors, combustion engines, chassis dynamometers, and other vehicle subsystems across the campus.

“To support such a wide variety of equipment and data exchange interfaces



Students in the engine dyno HIL lab.

across different labs, we needed tools that were quickly reconfigurable and flexible,” Dr. Brennan explains. “Our students needed to interface with this equipment without interfering with research projects going on in the labs, and they needed to conduct offline and online simulations.”

In addition, Brennan and Anstrom needed analysis and simulation tools that would enable students from a wide variety of disciplines to learn advanced vehicle powertrain analysis concepts quickly.

“C source code does not work well as a teaching aid,” says Dr. Anstrom. “We wanted the students to be able to visualize systems. We needed tools that could help us quickly explain a system in the classroom and that students could use on their own to explore concepts in more detail.”

THE SOLUTION

The Penn State instructors use MathWorks products in all lectures and labs in Advanced Vehicle Hardware-in-the-Loop Methods. “MathWorks tools enable students to do modeling, analysis, and controller design on a single platform,” says Anstrom.

THE CHALLENGE

To teach engineering graduate students advanced vehicle powertrain technologies using hardware-in-the-loop methodologies

THE SOLUTION

Use MathWorks™ tools to set up an interconnected campus-wide HIL network and help students apply high-level concepts, visualize results, and control real hardware

THE RESULTS

- Labs set up in minutes
- Career opportunities enhanced
- Research and teaching integrated

“ We wanted to standardize on one platform for the course, and we didn't want to have to teach that as well. With MathWorks™ tools, our students can do both modeling and analysis, and then develop an embedded controller without switching software platforms. That is invaluable. ”

Dr. Joel Anstrom, Penn State University

Each of the first four labs in the course focuses on the dynamics of one specific powertrain component: the battery pack, ultracapacitor, DC motor, or engine. In these labs, students use powertrain system models in Argonne National Laboratory's Powertrain System Analysis Toolkit® (PSAT). Based on Simulink, PSAT enables automotive engineers to analyze and simulate advanced powertrain technologies.

Using the PSAT model as a starting point, the students replace the software representation of a single component with real hardware. They use Real-Time Workshop® to generate code from the model and xPC Target to run real-time simulations, control the hardware, and collect simulation results. In the battery lab, for example, students use xPC Target to control and gather performance measurements from a power-processing system capable of producing up to 150 kilowatts.

In each lab, students use MATLAB® and Simulink® to analyze system behavior, compare simulated and measured results, and determine how the results might be used for advanced vehicle powertrain optimization.

In the final lab, students work with a full electric vehicle on a chassis dynamometer. They emulate the terminal response of a fuel cell using a power-processing machine driven by a Simulink model and xPC Target.

Brennan and Anstrom used Stateflow® to develop sophisticated control algorithms that manage startup and shutdown of the full electric vehicle to ensure safe operation. The controller was deployed on a standalone PC using xPC Target Embedded Option™.

They are developing a scaled-down version of a hybrid electric vehicle that students can use in the classroom to create their own control strategy and real-time controller.

THE RESULTS

▪ **Labs set up in minutes.** “We began designing the hardware and implementing the course material within a few weeks of acquiring MathWorks products,” says Brennan. “We were often able to set up a lab in minutes that otherwise would have taken days.”

▪ **Career opportunities enhanced.** “One of our students mentioned the HIL class during an interview for an internship,” says Anstrom. “The interviewer was really excited, and they talked about it for the rest of the interview. Thanks to his experience with MathWorks software and HIL, the student was offered an opportunity to work in the company's controls group.”

▪ **Research and teaching integrated.** “The MathWorks environment is extremely fast and very visual, which helps in classroom discussion,” Brennan says. “It is an excellent collaborative environment for research that carries over into the classroom.”

To learn more about Penn State University's GATE Center, visit www.vss.psu.edu/GATE.htm

APPLICATION AREAS

- Education
- Automotive
- Hardware-in-the-loop simulation
- Data analysis

PRODUCTS USED

- MATLAB®
- Simulink®
- Stateflow®
- Real-Time Workshop®
- xPC Target™
- Control System Toolbox™

www.mathworks.com

