Power Electronics for Hybrid Electric Vehicles

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Today's rapidly evolving products are getting smarter and often include complex interactions between components, subassemblies and systems. In industries such as automotive, aerospace and industrial automation, organizations use robust systems-level simulation to identify potential problems, early in the design stages, that other simulation or build-and-test methods cannot detect.

In particular, the automotive industry is steadily increasing the amount of power electronics in mechatronic applications as it keeps up with consumer, environmental and government demands. Engineers and system designers are turning to electric-drive systems for significant benefits of weight and cost reduction, increased reliability of electrical systems, and convenient control and automation via electronic means to improve efficiency.

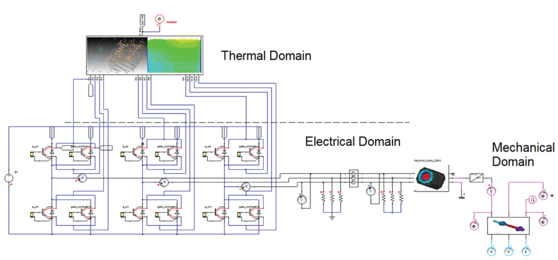

Figure 1. System simulation example of inverter, coupled with ANSYS® Icepack® thermal model, electric machine model and reduced-order model shaft

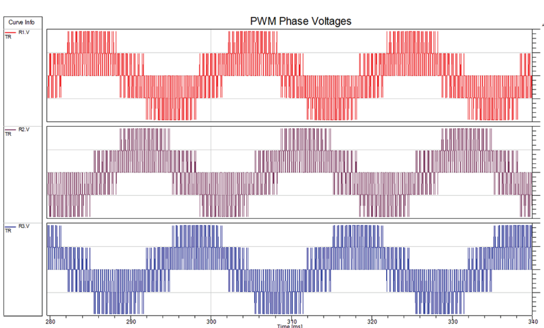

Figure 1a. Inverter output voltages

A multidomain approach to simulation with tightly integrated solvers enables engineers to model, simulate, analyze and optimize complex systems, such as electromechanical, electromagnetic, power electronics and other mechatronic designs. Design engineers can create efficient yet highly accurate models across multiple domains, leading to high-fidelity simulations of entire complex systems.

Power Electronics Design

Power electronic systems often include inverters, converters, electric machines, related mechanical or hydraulic loads, sensors, semiconductors (IGBTs switching at requested PWM frequencies), parasitic effects from circuit boards and cables, and control algorithms. Important issues to consider for design and management of these systems include semiconductor loss and thermal performance during cycling, surge currents and voltages during switching, and conducted and radiated emissions (EMI/EMC) due to increasingly higher switching frequencies.

Simulation software should support device and component characterization tools, including IGBT model generation of behavioral, average and/or dynamic models. Such capabilities allow users to easily select the fidelity of the simulation. These detailed models represent the electrical and thermal performance of the switching semiconductor device and, thus, are suitable for predicting thermal performance of the system.

Thermal performance is enhanced by extracting the thermal network of the power electronic enclosure. Methods of reduced-order modeling can very efficiently extract data from detailed CFD models for use in a system simulation, resulting in very robust electrothermal simulations of the power electronic systems. Using reduced-order models from detailed finite

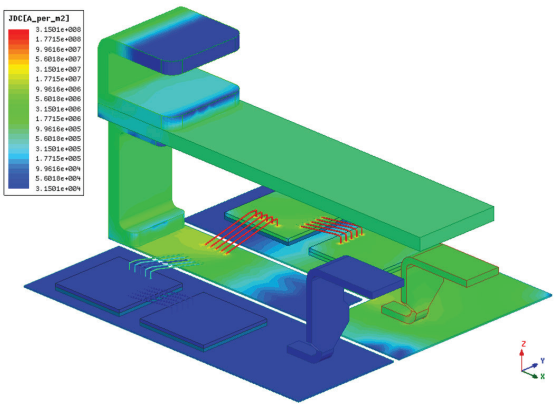

Figure 2. Single phase of IGBT leg showing current density

element or CFD models also yields benefits in other applications, such as modeling the electrothermal performance of battery systems, incorporating mechanical components from finite element analysis and including frequency-dependent magnetic models in the system simulation.

Parasitic extraction of impedances (R, L, C, G) of printed circuit boards, cables and bus bars is also important. Tools should provide a streamlined method for extracting these impedances as a function of frequency and including them in a system analysis, for example, or studying high-frequency power and signal integrity of circuit boards. Such capabilities are instrumental in addressing the design of circuit layouts, DC bus structures, IGBT power module structures, and interconnection of variable frequency drives and grounding structures. Using these calculated impedances in power electronic system simulations can help designers to increase power ratings and reduce or eliminate the use of snubber circuits. Furthermore, this allows the simulation to address the conducted or radiated emissions of the system and to simulate methods for meeting EMI specifications and increasing overall power quality.

In addition, a coupling functionality is essential to allow designers to include the detailed electromagnetic performance of transformers, inductors and electric machines into their system simulations. Finally, a flexible platform provides users with a schematic view of the entire simulation. Benefits include incorporating requirements and specifications of different system architectures and system performance when using different components.

Whether the challenge is to develop an electric propulsion system, integrate an electric drive with a motor, or create a new alternative energy system, simulation technology is essential to virtually explore every aspect of the design — and to deliver it quickly, accurately and under budget.

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