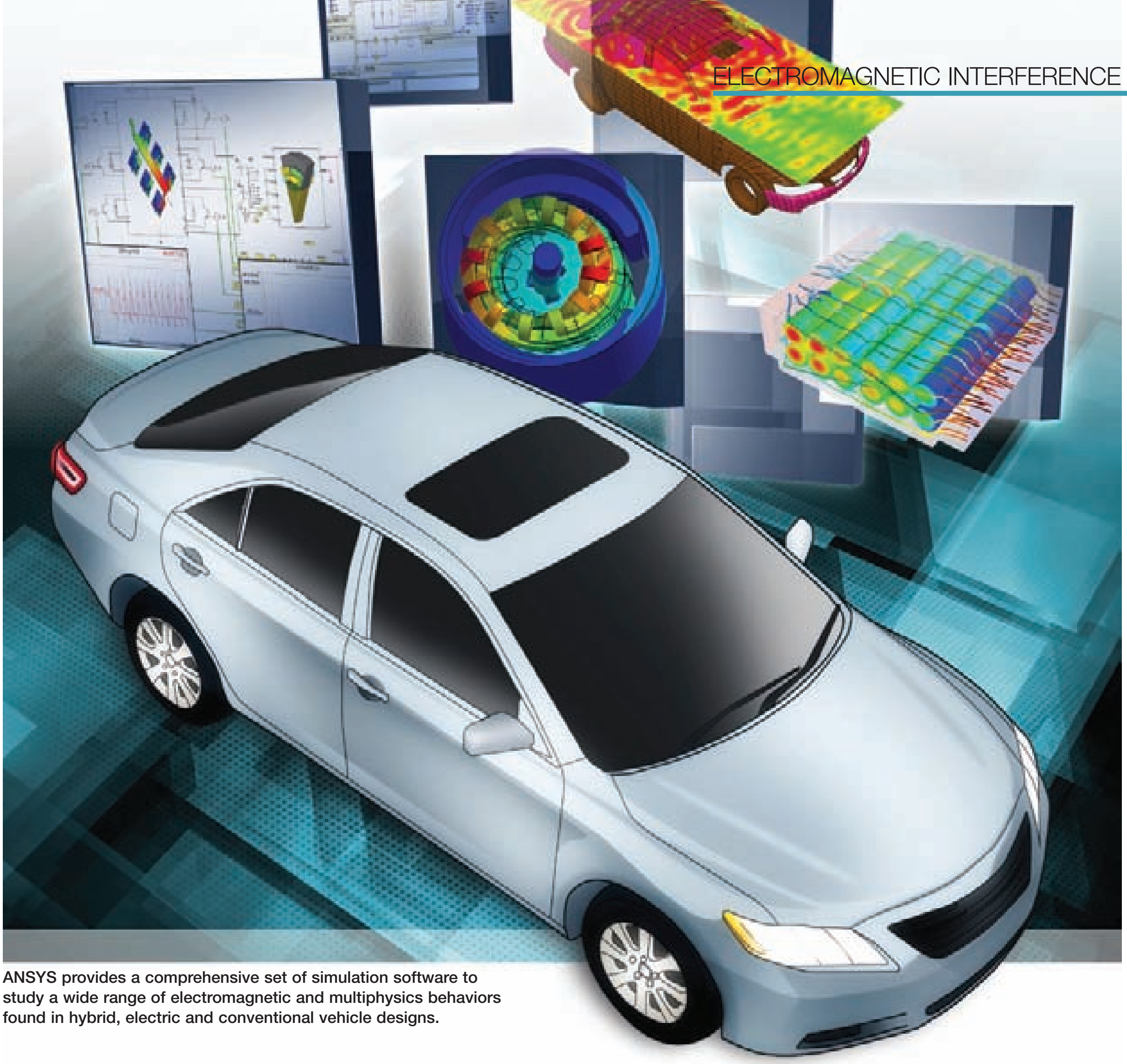


ANSYS provides a comprehensive set of simulation software to study a wide range of electromagnetic and multiphysics behaviors found in hybrid, electric and conventional vehicle designs.

Simulation-Driven Design for Hybrid and Electric Vehicles

Simulation helps to identify and correct EMC/EMI problems early in the development of innovative, next-generation vehicles.

By Scott Stanton, Technical Director of Advanced Technology Initiatives and Mark Ravenstahl, Director of Marketing and Communications, Ansoft product group, ANSYS, Inc.

In the highly competitive hybrid electric and electric vehicle (HEV/EV) market, powertrain engineers are challenged to increase system efficiency, stability and reliability. Power inverters play a critical role in powertrain systems. Typically comprising six insulated-gate bipolar transistor (IGBT) modules in a 4-inch by 6-inch package, these devices switch hundreds of amps of electrical current on and off very rapidly to provide ac power for the motor, control electronics and other systems. IGBT switching frequencies can range from tens to hundreds of kHz, with turn-on rise times and turn-off fall times in the order of 50 to 100 nanoseconds.

The fast switching speed of these devices makes IGBTs extremely effective in power inverter systems, but this switching speed is also the source of two major electromagnetic problems. Conducted emissions (through current-carrying structures) are generally less than 30 MHz and can cause power integrity issues or set up reflected waves of energy that can potentially damage the inverter and the motor. Radiated electromagnetic fields (through air) are generally greater than 30 MHz and can affect the rest of the vehicle's many electronic systems.

Both types of interference problems must be considered in meeting the required government and international vehicle electromagnetic emission standards, so engineers responsible for power inverter systems must design for electromagnetic compatibility/electromagnetic interference (EMC/EMI) in the fundamental architecture of that system. This can be accomplished only by first solving for the underlying physics that govern the behavior of EMC/EMI and then leveraging those solutions across circuits and systems. This simulation-driven approach has the advantage of addressing other electromagnetic issues that must be taken into account, including electrical current quality, power dissipation and the efficiency of the overall system.

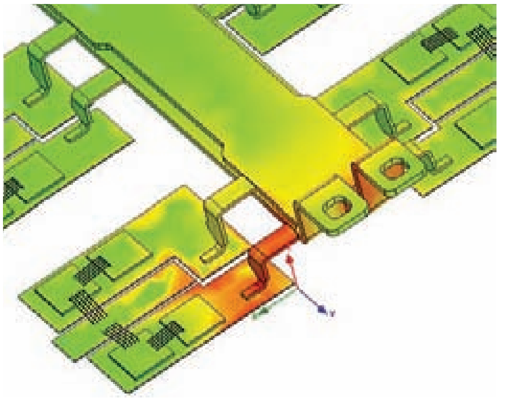
Typically, performing these calculations using linear circuit elements and simple circuit solvers requires numerous gross approximations and overly simplified assumptions. By skipping the crucial step of simulating the underlying physics, however, results will not be correct, and several hardware prototype test-and-redesign cycles may be completed before satisfactory performance is achieved. In most cases, these testing cycles cannot take place until late in the design process, when costs can escalate significantly and delays can lead to missed market opportunities. Predicting today's electromagnetic effects in the early stages of development, before the power inverter is built, is virtually impossible without the use of multiphysics simulation.

A full range of such multiphysics tools for studying the electromagnetic behavior of equipment such as IGBTs is available in the Ansoft suite of software, which specializes in electromagnetic field simulation as well as circuit and system simulation. Ansoft tools particularly useful in power inverter development include:

- Simplorer — a multi-domain circuit and system simulator that can easily integrate components across electrical, thermal, mechanical, magnetic and fluidic domains
- Q3D Extractor — a quasi-static computational field solver for the calculation of frequency-dependent resistance, inductance, capacitance and conductance parameters of current-carrying structures
- HFSS — a finite element–based full-wave solver for extracting parasitic parameters and visualizing 3-D electromagnetic fields

To accurately characterize the behavior of a switching device such as an IGBT, engineers typically begin by using a parameterization wizard that takes into account performance curves and tabular data from specification sheets available from the vendor. This process automatically extracts the required parameters (approximately 140) to aid in creating a semiconductor circuit model of the IGBT — instead of having to perform this task manually.

Next, the physical layout of the power inverter is imported from a CAD geometry or layout tool into



Q3D Extractor model indicates current distribution of an IGBT package.

the Q3D Extractor tool. From the physical layout, Q3D Extractor computes the frequency-dependent resistance, partial inductance and capacitance (RLC) along the conduction paths. Engineers then use the tool to create an equivalent circuit model for the system simulation in Simplorer software. Once this representation is created, it can be used in conjunction with the semiconductor circuit model to create an electrically complete model of the IGBT. This can be used with the power source, control system and load to analyze conducted emissions.

The results of these simulations can be used with HFSS software to examine radiated emissions — a particular concern considering the frequency harmonics created as a consequence of the fast turn-on/turn-off times. To determine this effect, results from the Simplorer tool can be used as input to the HFSS full-wave electromagnetic solver. The engineer then can obtain a complete understanding of radiated fields and can calculate the intensity at any given point in space to determine if the inverter package is in compliance with standards.

Using this approach, the engineer can use Ansoft tools to design for EMC/EMI problems in the inverter system and trace the source of the behavior back to the physical layout of the device. The design can then be parametrically varied and a series of simulations performed until conducted and radiated electromagnetic emission levels are within acceptable limits. The value of the method is that, once the models and various representations are complete, they can be readily modified by changing a few key parameters, which allows engineers to study various alternatives and explore a wide range of what-if scenarios. The approach provides a design that is within specifications and entirely optimized — all before a single piece of hardware is built. In this way, the multiphysics-based simulation approach saves time and money compared to building and testing prototypes, and it enables companies to beat the competition to market with better designed products. ■