MULTIPHYSICS SIMULATION

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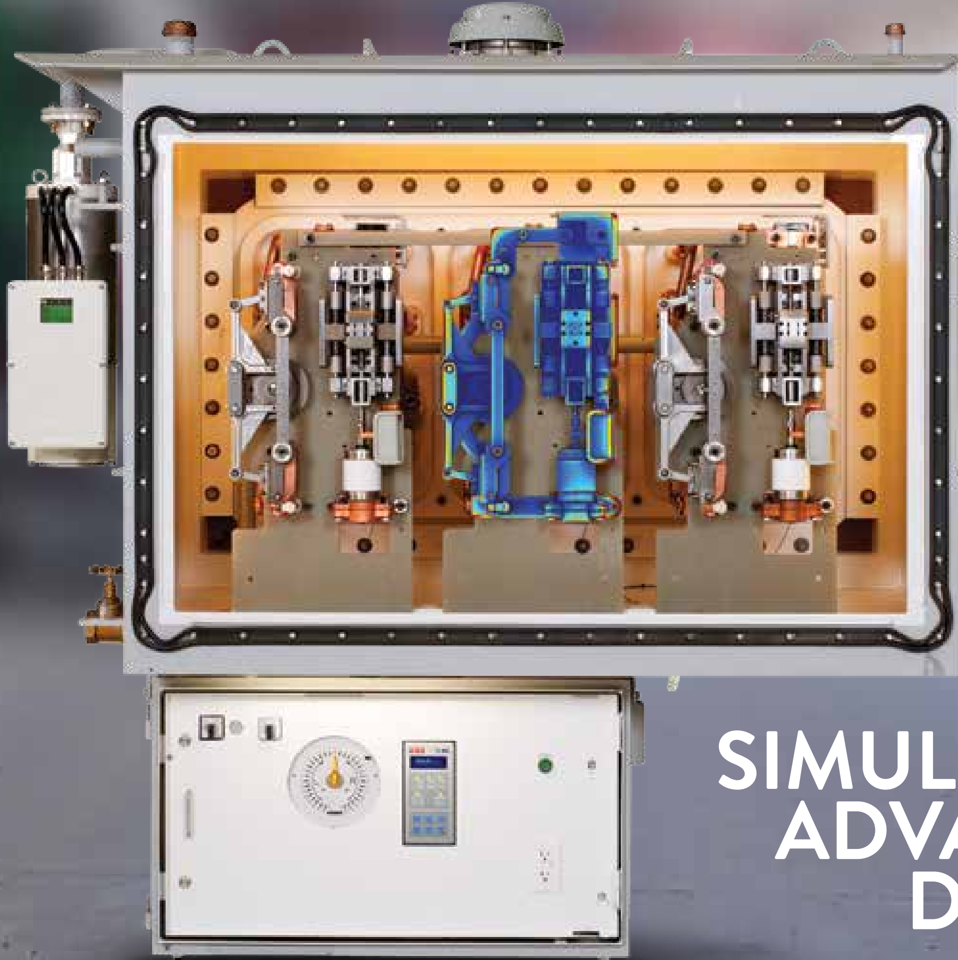


SIMULATION ADVANCES DESIGN AT ABB

PAGE 20

MULTIPHYSICS SOFTWARE, A VERSATILE, COST-EFFECTIVE TOOL

PAGE 3

PUSHING THE LIMITS OF CHIP DENSITY

PAGE 29

CONTROL OF JOULE HEATING EXTENDS PERFORMANCE AND DEVICE LIFE

Fuses and bus bars, which are everyday components in large electrical systems, carry very high currents. Understanding their failure mechanisms with simulation can lead to added safety in the systems where they are employed, along with improved manufacturing

By **JEAN-LOUIS GELET AND ANTOINE GERLAUD, MERSEN FRANCE**

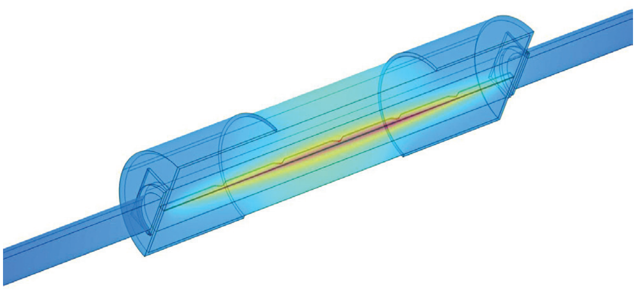


FIGURE 1: A simulation shows the heat distribution through a fuse that has not yet blown.

MERSEN IS AN international company whose product expertise extends to overcurrent protection, surge protection, high-power switching, cooling of power electronics, and power transfer for railway systems. Our group within the company addresses electric protection. In the last few years, we have introduced simulation into our design work flow, and up to now we have been studying various components, with some interesting results. Previously, our designs were based primarily on trial and error. Now we use COMSOL Multiphysics instead to design and optimize these fuses and bus bars.

» ELECTRIC PROTECTION: IT'S ALL IN THE FUSES

EVERYONE TAKES FUSES for granted in protecting equipment of all types. Examples at the high end include photovoltaic systems and wind turbines that can have voltages up to 1500 volts and currents of hundreds of amps. At the other end of the spectrum are semiconductor devices, which require high-speed fuses because they are so sensitive to overcurrents. The performance characteristics of such chips continue to evolve, along with the safety requirements we need to address.

No matter what the size of a fuse, it operates on the same basic principle. A strip of metal heats up, and if excess current flows, it vaporizes. When a fuse melts, an electric arc bridges the gap, and until the gap becomes too wide for the arc to bridge, the fuse continues to conduct. Further, the arc can be dangerous to people, equipment, and the environment, so it must be quenched. Especially for large currents, an air gap alone is insufficient to prevent the arc and would result in an unacceptably large fuse. A porous material such as sand is therefore added to absorb the energy and quench the arc. This results in a faster-acting fuse that interrupts the current before it can reach its maximum intensity. Indeed, managing the arc is the most challenging aspect of our fuse design work.

Thanks to simulation (see Figure 1), we can adjust the fuse element thickness and cross section to obtain the desired thermal response, understand what is actually happening inside the fuse, and reduce the overall dimensions of the protection device.

» POWER TRANSFER: AVOIDING HOT SPOTS IN BUS BARS

IN CASES WHERE it is necessary to conduct large currents across a short distance and to many loads, it often makes sense to replace individual, thick cables with a single piece of conducting metal, called a bus bar. In our case, our bus bars are actually laminates with a film of insulating material inserted between conducting plates at different potentials in order to guarantee electrical insulation; this film must be glued on in order to avoid any displacement, and this gluing also con-

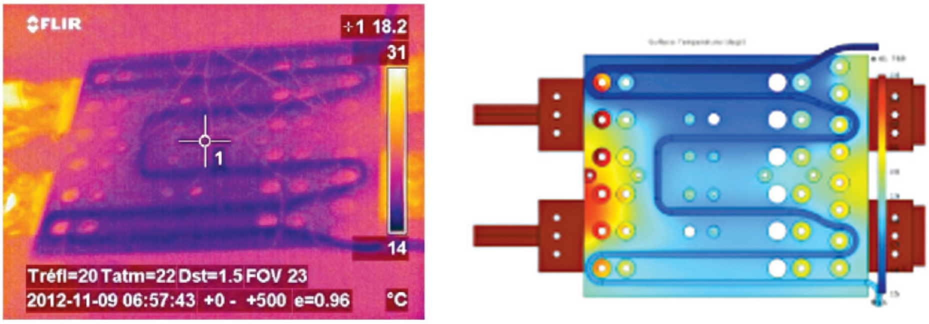


FIGURE 2: Thermal image of a bus bar (left) and the equivalent simulation (right).

tributes to the assembly of the conducting plates.

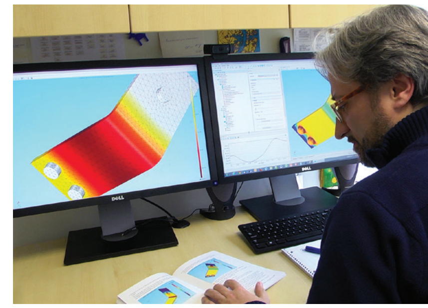
If the temperature in a bus bar goes too high, the glue or insulation can be destroyed. In the worst case, there can be a dramatic short circuit with extremely high levels of current, which can be 400 amperes nominal and 50 kiloamperes in a short-circuit situation. And if the glue is destroyed, there can be considerable mechanical deformation, such as wrapping and bending of the bus bar due to Laplace forces, i.e., magnetic forces acting on current-carrying conductors. In fact, we are now expanding our model to study the mechanical effects due to short circuits.

The primary goal of our present simulation is to determine the temperature field generated by the Joule effect, and this lets us adjust the thickness of the conducting plates and eliminate any hot spots we identify. COMSOL Multiphysics gives us more knowledge about what is going on inside the various layers. This is in contrast to the thermal image, which only shows the emissivity of the component on the surface. For bus bars, validation is performed by comparing the results of a simulation with a thermal photograph (see Figure 2).

Mersen has concentrated its efforts up to now on thermal modeling. Among the larger benefits are an improvement of the physics and a reduction in testing and development costs. Heat mappings are very useful for communications with customers.

Our next project will consider the fact that products are used in the field in nonstandard conditions. Based on models of products operating under standard conditions validated by tests at the lab, it will be possible to simulate operation in a customer's nonstandard conditions. It will also be possible to investigate the question of on/off operations using transient simulations. ◎

JEAN-LOUIS GELET *(left) and* **ANTOINE GERLAUD** *(right), both of Mersen Electrical Protection. They are holding a bus bar similar to those tested in the lab.*



INTRODUCTION TO COMSOL MULTIPHYSICS

Everyone takes fuses for granted but might not be aware of bus bars, which are widely used and represent important elements in the electric power transmission industry. They also represent a truly multiphysics example of a common natural effect, Joule heating. Given the importance of understanding how Joule heating can affect everyone's designs and its intrinsic multiphysics nature, COMSOL decided to adopt bus bars as an example to help users learn the software, grasp the simulation work flow, and understand multiphysics. The new version of the Introduction to COMSOL Multiphysics book is now available for download at www.comsol.com/introbook.