InCa3D: Capacitive Effects for E M C Analysis

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Last April, CEDRAT released 3.1 version of InCa3D, the tool designed for "Conductor impedance and near field" simulations of electrical interconnections.

Just a word to explain what electrical interconnections in EMC and Power Electronics applications are.

It is a set of metallic conductors that link electronic components, i.e. to allow the electric current to flow from one component to the others. Unfortunately, the electromagnetic behavior of such wiring conductors is not an ideal short-circuit, which means that there is a voltage drop between two different points of the interconnection. In the device or system under consideration, some undesirable effects crop up, like **extra-losses**, **overvoltages** on components, **dissymmetry** on currents flowing in parallel paths, **common-mode** couplings, etc.

All these phenomena degrade the device performances and need to be kept under control by designers during the development of an electronic product; in other words, parasitic effects (resistive, inductive and capacitive) of electrical interconnections need more and more to be taken into account by ad-hoc simulations. InCa3D is the CEDRAT software covering such necessity.

Examples of "cabling" systems

The figure below lists some examples of devices where connecting conductors are significant and where InCa3D simulations are useful: they are positioned on a two-dimensional graph with working frequency and power on the abscissa and ordinate axes, respectively. At low frequency (hundreds of Hz), systems can drive higher power, while energy quantities are lower inside devices that work at high frequencies (hundreds of kHz).

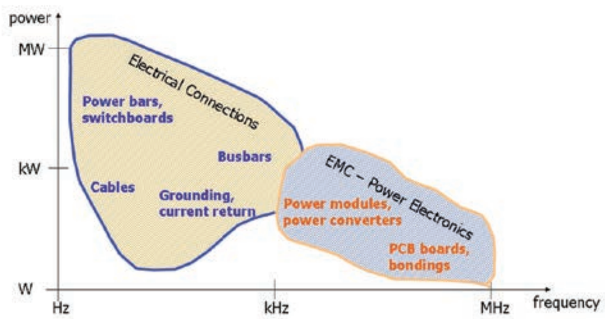

Figure 1: Examples of interconnections analyzable by InCa3D.

Even though the borderline is really ephemeral, it is interesting to organize the devices into two families because the technical points and issues the designer faces are not the same. The first group, which we can call **Electrical Connections**, includes elements like cables, distribution bars, switchboards, busbars and grounding systems where skin and proximity effects have a strong impact on device performance. Parasitic phenomena to be assessed are essentially resistive and inductive, whereas physical quantities to control include current distributions, power losses and electrodynamic forces.

In past issues of this magazine (cf. n°66), we presented examples where InCa3D was successfully applied to analyze and improve the design of such structures. The aim of this article is mainly focused on the second family, namely **EMC – Power Electronics**, since the new version of the InCa3D software provides a key functionality for the analysis of devices like power modules, power converters and adjustable speed drives: computation of the capacitive couplings between conductors.

> *Common-mode currents, flowing for example between the power/ground conductors and the heat sink, are one of the main reasons behind EMC failures.*

In fact, when working frequencies are higher and harmonic distortions (tens of MHz) need to be assessed, the effects of parasitic capacitances are no longer hidden by the inductive behavior of the interconnection, but they can become the main cause of malfunction.

Benefits of the new InCa3D version

Version 3.1 of InCa3D opens the door to these investigations, since it provides all the elements of the capacitance matrix between the conductors, possibly separated by dielectric substrates. The power electronics designer can easily find out where most **critical parasitic capacitances** are and judge - in the early stages of product development - whether or not risks are acceptable.

Parasitic **capacitance matrix** between regions, values in **pF**

	PCB_P	PCB_M	PHASE1	PHASE2	PHASE3	PLUS	MINUS	HEAT
PCB_P	0	56.46	4.15e-3	4.03e-3	8.93e-3	65.09e-3	7.99e-3	755.6e-3
PCB_M	56.46	0	83.07e-3	68.96e-3	63.49e-3	120.3e-3	49.27e-3	1.462
PHASE1	4.15e-3	83.07e-3	0	64.74e-3	0.834e-3	11.07e-3	54.00e-3	18.66
PHASE2	4.03e-3	68.96e-3	64.74e-3	0	75.32e-3	13.73e-3	60.79e-3	15.81
PHASE3	8.93e-3	63.49e-3	0.834e-3	75.32e-3	0	7.35e-3	23.08e-3	16.42
PLUS	65.09e-3	120.3e-3	11.07e-3	13.73e-3	7.35e-3	0	37.77e-3	44.33
MINUS	7.99e-3	49.27e-3	54.00e-3	60.79e-3	23.08e-3	37.77e-3	0	12.33
HEAT	755.6e-3	1.462	18.66	15.81	16.42	44.33	12.33	0

Figure 2: Parasitic capacitance matrix computed by InCa3D.

Once the capacitance matrix is obtained, the InCa3D user can - in the same software environment, thus cutting down working time - build and solve the **global models** composed by these capacitances and the resistive-inductive behavior of the structure. Several interesting results are produced by this RLC computation.

The so-called "Conductor Impedances" application provides the engineer with a feature to plot 2D curves of the impedances as a function of frequency and consequently to reveal the values of the **system's electrical resonances**. This analysis allows the engineer to check whether critical harmonics of the switching signals are in this band and, if necessary, to adjust the design to shift them.

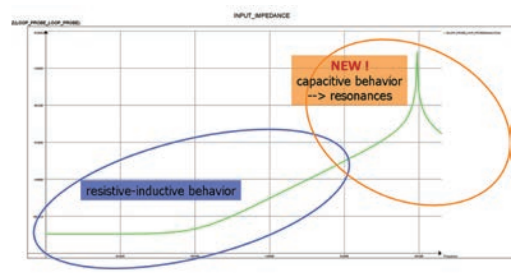

Figure 3: Curve of the impedance Z(f) showing system resonance.

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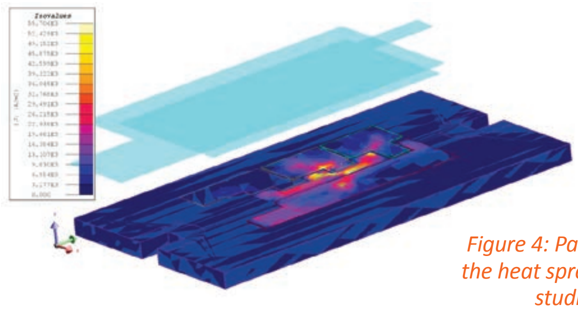

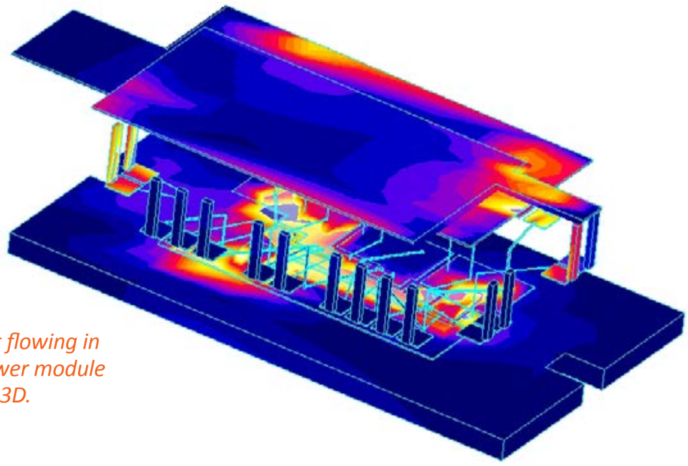

Figure 4: Parasitic current flowing in the heat spreader of a power module studied using InCa3D.

To go into greater depth on the study of harmonic distortions, time-domain simulations are sometimes necessary: within circuit-level tools, the functional scheme of the power module or converter is thus supplemented by the parasitic behaviors of the interconnections. InCa3D also fulfills this need, since it has the ability to extract accurate **equivalent RLC circuits** in the most common standard languages (SPICE, VHDL-AMS). This enables the power electronics designer to evaluate the amplitude of the overvoltages that can damage the switching components or cause premature aging.

The other InCa3D application, namely "Supplied Conductors", is historically dedicated to – amongst other things – the study of current distribution flowing inside conductors. Since global RLC models are developed in the new 3.1 version, this InCa3D application also provides the user with the value of the current inside all the parasitic capacitances for each frequency.

These currents, flowing between the power/ground conductors and the heat sink for example, are the origin of **common-mode noise** which is often difficult to investigate by measurement and which is one of the main reasons behind EMC failures during final qualification tests of power electronics devices. Being able to explore such behaviors by simulation is a great benefit: it reduces development time for the product and makes it possible to respect time-to-market constraints.

For more information:

>> www.cedrat.com/Software/InCa3D