EMC Investigations on Industrial Inverter.

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There is high demand in simulation tools for EMC requirements as these considerations are increasingly the key focus of design teams. This paper aims to present how existing software, InCa3D, has been used to provide interesting results on an industrial inverter. The structure studied is presented in the first part and a focus is done on the models obtained with InCa3D on the initial structure and two improved prototypes. The second and third parts present the results obtained on the transfer function and near-field emissions respectively. The paper ends with some perspectives on further studies made in the domain.

System under study

The inverter studied is a Schneider Toshiba Inverter Europe three-phase motor driver. Its structure, as presented in figure 1, contains a filter composed of a common mode inductance and several capacitances. This leads to a resonance frequency that needs to be evaluated in relation to the working spectrum. Besides, one has to take into account the effects of the grounded capacitances which offer a path for common mode currents. The rest of the inverter is composed of a rectifier / inverter structure associated to a cable which feeds an external machine. This part of the structure is not involved in the study presented here and therefore has been represented as an external excitation source.

The focus is set on the filter part and more particularly, on the influence of the cabling on the filter's EMC efficiency. Previous studies [1] have underlined the requirement to take into account the cabling conductors, and the results presented in figure 2 clearly show this effect.

The initial structure of the filter contains two kinds of connections with routed conductors on a PCB on one side and some cables on the other. Two test prototypes were constructed in order to reduce the harmful influence of those cables using PCB tracks instead of them. It is important to note that this can lead to a higher number of layers and thus – although not the case here – to new routing technologies. In the first prototype, component placement remained unchanged, leading to quite long PCB tracks which can cause disturbances. In the second prototype the positioning of the components was changed in order to reduce the size of those tracks. Three topologies were modelled with the InCa3D software and figure 3 shows the corresponding models.

InCa3D software aims to model electric conductors and thanks to a well adapted and very fast solving method PEEC (*Partial Element Equivalent Circuit*)) it provides results like equivalent impedance or current and field analysis. In the particular case of this study, only conductors of the filter were modelled and, as mentioned previously, the rest
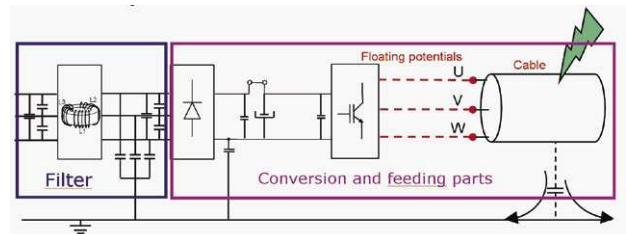

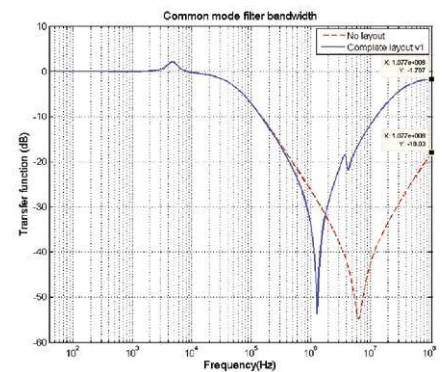*Fig 1: Structure of the industrial inverter studied.*

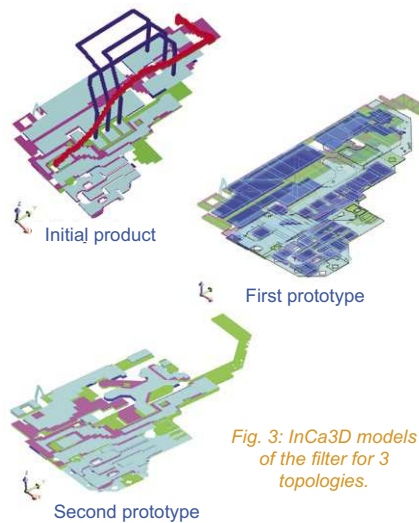*Fig 2: Common mode filter transfer function with and without layout consideration.*

Fig. 3: InCa3D models of the filter for 3 topologies.

Initial product

First prototype

Second prototype

of the industrial inverter was modelled by equivalent sources representing the common mode current excitation. The same excitation source was used for the three topologies to facilitate comparison of the results.

Cabling improvement regarding transfer function

InCa3D makes it possible to export the results from the impedance matrix computation to common circuit simulators like Portunus, Saber or Spice. The macro model thus exported can then be used for a complete analysis with all additional components of the structure. Figure 4 explains the principle of the diagram which is entered into the circuit simulator. To the generic PEEC model of the cabling, a model for a LISN (Line Impedance Stabilization Network), the inductance, the equivalent source whose role was explained in the previous section, several capacitances were added. From this global model the transfer function of the filter (for the three phases) can be obtained and figure 5 details results obtained for one phase for the three tested topologies. Complete results can be obtained in [2].
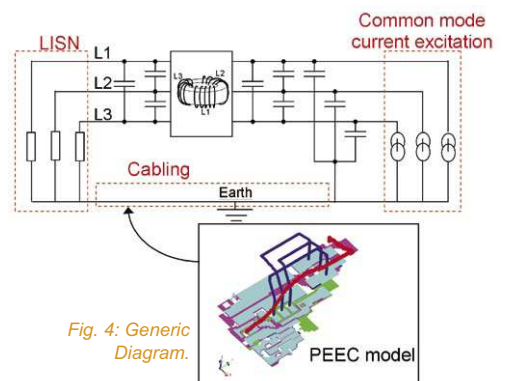

Fig. 4: Generic Diagram.

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The first conclusion that can be drawn from these results is that for this aspect of the EMC efficiency of the filter, Prototype 1 does not provide worse results than the initial topology. Results for prototype 2 confirm the fact that cabling has an influence on the performance of the filter. Besides, filtering efficiency was improved for Prototype 2 compared to Initial Product and Prototype 1.

But these results are not sufficient to draw conclusions as to the topologies tested. In fact, the EMC efficiency analysis is not limited to the study of the transfer function. Results like the near field emissions are part of this process too.

Influence on near field emissions

The near field emitted by the structure can be obtained directly in InCa3D and does not need any coupling to other modelling software. Excitation sources can be added to the geometric model of the cabling, making it possible to obtain a cartographic representation of the magnetic field emitted outside the structure as displayed in figures 6a & 6b, with a comparison between *Initial topology* and *Prototype 1*. The important element in these results is that the maximum magnitude obtained for the magnetic flux density radiated was reduced almost three-fold between the Initial Topology and Prototype 1 and the trend was validated by the measurements [3] made. These results can be seen on figure 7.

It is worth noting that the results provided by InCa3D in this case do not represent exactly the reality as all parts of the structure except the filter cables were represented by equivalent sources. Nevertheless, a relative analysis between initial topology and prototypes makes it possible to test the EMC efficiency improvements achieved.

Perspectives

The study presented in this paper could be extended to a larger scale and with more accuracy by considering more than just the filter in the modelling. Research has been done to take into account the influence of the common mode inductance thanks to a coupling between the Finite Element Method and PEEC [4]. Other studies have been undertaken to test the influence of shielding around that inductance [5].

This article has presented how the use of InCa3D models was an essential point for the investigations made on the EMC efficiency of the industrial inverter studied. Thanks to several results and export possibilities of the software an optimisation process was followed to improve the EMC performance of the structure. The software proved to be an essential tool for the modelling and optimisation of power electronic structures in order to reduce design costs and time.

References

[1]- "Influence of the cabling geometry on paralleled diodes in a high power rectifier"- E. Clavel, J. Roudet, J.L. Schanen, A. Fontanet - IAS 96
[2] – "Determination of the layout influence on the effectiveness of a three-phase common mode filter by using equivalent circuits and PSpice" - J. Aimé, E. Clavel, J. Roudet, P. Baudesson, - ISIE 08
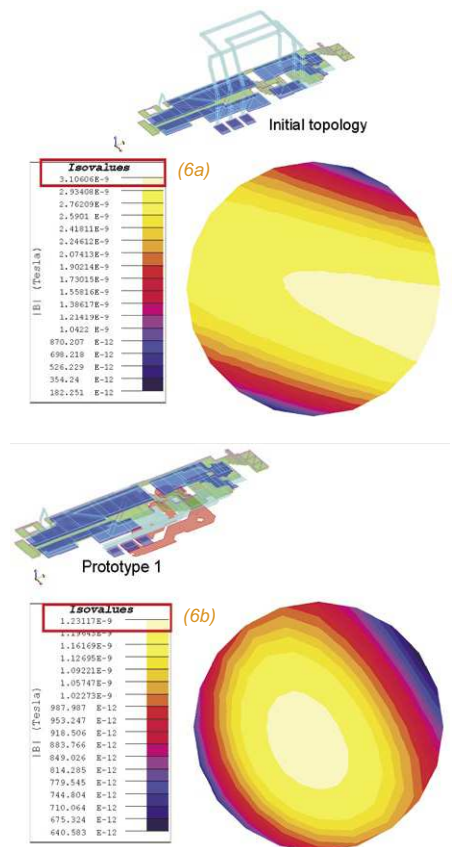

(6a)

(6b)

Fig. 6a: Initial topology - 6b: Prototype 1.
Near field (B) radiated around the filter simulated with InCa3D.

[3]- "Prediction and measurement of The magnetic near field of a static converter"- J. Aime, J. Roudet, E. Clavel, O. Aouine, C. Labarre, F. Costa, J. Ecrabey - ISIE 07
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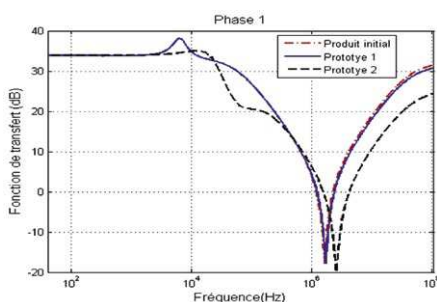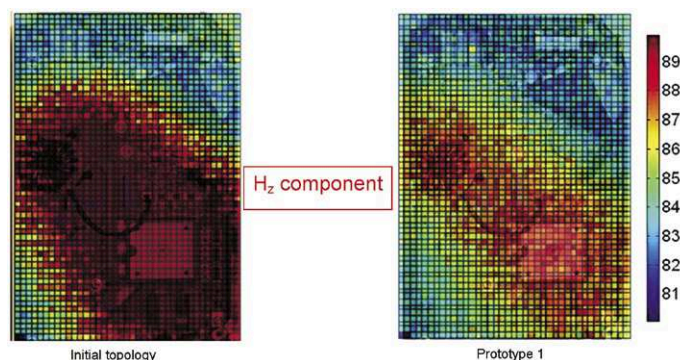
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Fig. 5: Function transfer comparison for Phase 1.

Hz component

Fig. 7: Measurement results on magnetic field.