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# MODELLING PROCESS AND OPTIMISATION OF EMC FILTERS FOR POWER ELECTRONICS APPLICATIONS

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**Abstract.** The paper proposes an approach for easy and fast modelling and optimization of power electronics structures. It focuses on the EMC filter design. To achieve this task for electrical drives, a full EMC modelling of the application is defined by combining time simulation, FFT and automatic frequency modelling. The automatic modelling gives also automatically the model gradients. This process is very generic, fast and systematic, and can be used with any optimisation algorithm, using gradients or not. Therefore, the model can be used to optimize the EMC filter, but also can help in choosing its topology, according to the technological choices of the aircraft power electronics specifications.

**Keywords:** EMC, Filter design, automatic frequency modelling, Optimisation.

## INTRODUCTION

There may be a great impact of the electromagnetic behaviour due to the power electronics of the electrical systems in several applications. In aircraft application, global weight, cost and volume of the equipment are also important complementary constraints. So, there is a strong need in helping the power electronics designers to choose among various technological possibilities, and to know the impact of these choices on all these constraints. The electromagnetic compatibility (EMC) filter usually represents roughly 30% of the cost and volume of a power electronics converter; so, it is very important to optimize it (Fig. 1). The impact of the converter control law, semiconductor choice, interconnection design, cable selection and placement, electrical machine characteristics... should be perfectly known to reach a good system design.

The paper proposes an aid in the frequency modelling of the drive elements, in the frequency domain, including all key parameters for sizing aim; and so, a way to optimize the filter using different algorithms available in Cades® framework [1] (see Fig. 2), but also in the Matlab® environment.

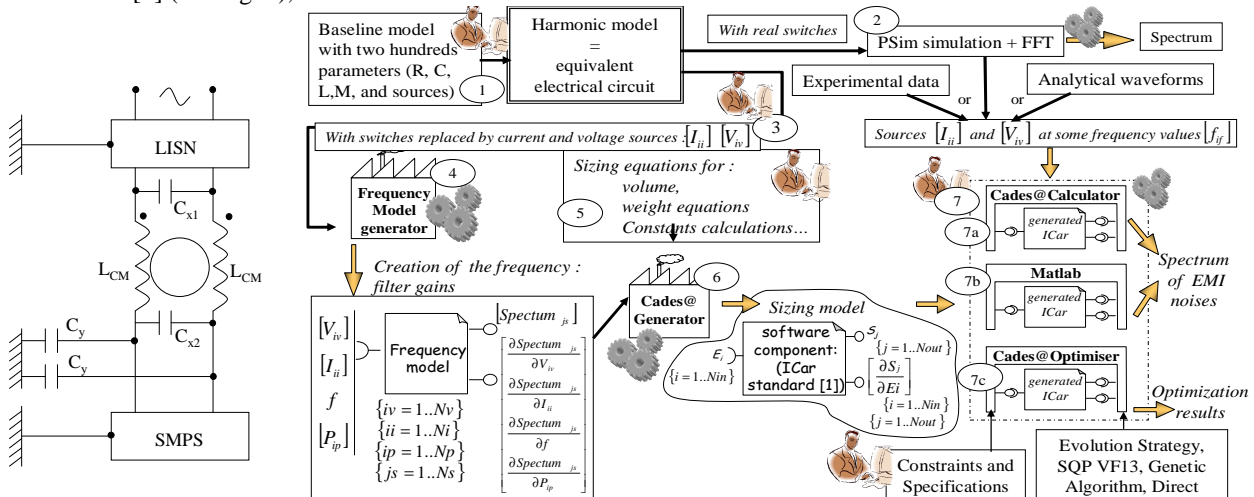


Figure 1: EMI Filter

Figure 2: Modelling and optimisation processes for filter optimization

## SISING MODEL

The process to build the sizing model is carried out in 6 steps (bubbles 1 to 6 in fig. 2). First, the designer defines an equivalent electrical circuit of its power electronics application (bubble 1 in fig. 2): LISN (Line Impedance Stabilization Network: the electrical circuit used to measure EMC disturbances), cables, static converter,

switches, electrical machines, ....[2]. Each element brings a contribution to the global EMC model. The principle of the modelling is to replace the switches by equivalent sources [2], [4] depending on the control law and semiconductor technology, which impact on switching wave forms (bubble 3 in fig. 2). The other parts of the system (i.e.: filter elements, bus bars, harnesses, machine) are represented using electrical equivalent circuit. Obtaining the equivalent sources can be achieved using simplified analytical waveforms, or experimental data or time simulation + FFT. This latter method has been chosen in this paper, using Psim software [3] (bubble 2 in fig. 2). After this modelling step, the paper proposes a new tool to create automatically the frequency model of the corresponding new circuit. The outputs of this model are some current or voltage gains:  $\{Spectrum_{js}, js = 1..Ns\}$ . The model inputs are: the frequency ( $f$ ), the voltage and current sources ( $\{V_{iv}, iv = 1..Nv\}$  and  $\{I_{ii}, ii = 1..Ni\}$ ) and the electrical parameters ( $\{P_{ip}, ip = 1..Np\}$ ) of the circuit. The gradients of the model outputs according to the model inputs are also generated. The model is created in java language (bubble 4 in fig. 2). Then, the designer defines other sizing constraint, e.g. volume or mass of components (bubble 5 in fig. 2). From that, Cades@Generator [4] is used to create a software component, supporting the computation of the entire sizing model and its gradients). These modelling steps, and specifically the frequency modelling step and the gradients calculation, will be detailed in the full paper.

### OPTIMISATION

The last step of the approach is the use of the generated software component, i.e. the sizing model (bubble 7 in fig. 2). The frequencies and the corresponding values of the voltage and current sources ( $V_{iv}$  and  $I_{ii}$ ) are obtained from PSim simulation and fixed in any calculation or optimisation. These hypothesis has shown acceptable results in previous works [1][3][5], and allows the use of linear modelling of the equivalent circuit.

For simple calculation, Cades@calculator and Matlab can be use to drive the generated software component [4] (bubbles 7a and 7b in fig. 1). Notably, due to the fact that only some harmonics are considered, computation times are drastically reduced compared to FFT on PSim simulation. Also, for optimisation, (bubble 7c in fig. 1), several algorithms can be use, even with gradients (SQP-VF13 [6]).

As illustrated in Fig.3, the filter has to meet the DO160D standard, which is required in our aircraft application. At this stage, the filter values have been obtained and the main volume (Fig. 4) is optimized by using the Evolution Strategy algorithm (Fig.4). The computation of the volume of inductances and capacitors will be detailed in the full paper. First results are illustrated below.

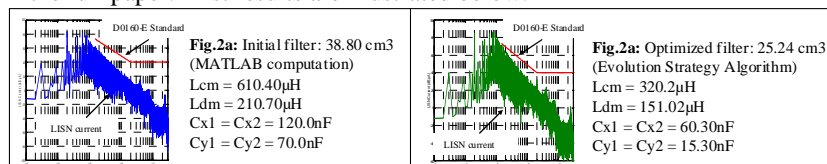


Figure 3. System simulation with filter before and after optimisation

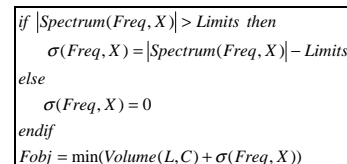


Figure 4: objective function

### CONCLUSION

It becomes especially important to manage the filter design and the impact of the system volume, weight and cost, specifically in aircraft applications. The use of a simple model, based on disturbance sources allows obtaining quickly an estimation of the EMC spectrum of an electrical drive, including the influence of all the parameters involved in the design: control, power package, busbar, harnesses and machine. The paper proposes a way to easy achieve such a modelling, allowing to carry out any optimisation algorithm thanks to automatic gradient computation. The automatic modelling reduces the modelling task, so allow optimizing on several power electronics architectures and several equivalent circuits for every architecture.

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