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From a Continuous and Imaginary Design to a Real Device: a Heuristic Strategy Dedicated to Power Electronics

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Abstract. Designing in a continuous and differentiable design space offers a lot of possibilities. But in a domain such as power electronics made with discrete components, it is necessary to come back in the real world starting from the previous continuous imaginary space. This paper offers a heuristic discretization process illustrated with an Interleaved Buck Converter.

Keywords: discretization process, imaginary world, power electronics design

INTRODUCTION

In the early step of a design process, the degree of freedom is large for the designer [1] that is why we propose to use gradient based optimization method (named 1st order optimization) for the design of power static converters [2]. This method requires continuous and differentiable models that are used for designing in the “imaginary world”. But in the reality, static converters are made of discrete components. The question is how to come back in the real world from the imaginary world? The paper will first present the concept and the difficulties of designing in the imaginary world. Then a discrete process will be proposed and illustrated with an Interleaved Buck Converter (IBC) design and finally a discussion will be opened on that proposal.

CONCEPT AND DIFFICULTIES OF DESIGNING IN THE IMAGINARY WORLD

Designing a system in the imaginary world (Figure 1), it is taking off the barriers that come from the discrete variables of the system. It means that the designer can imagine solutions that are not achievable in the reality thus moving away from conventional designs and get new ideas. So it allows exploring a larger area of possibilities thanks notably to the gradient based optimization algorithms coupled with genetic ones (hybridization). Of course, this asks continuous and differentiable models but not only.

Once the designer or the algorithm has found an optimal imaginary solution, the question is how to come back in the reality? Based on the imaginary optimal solution, it is not always easy to find the best combination of the discrete variables to make a workable system.

Especially for power static converters that are only made of discrete topology and components.

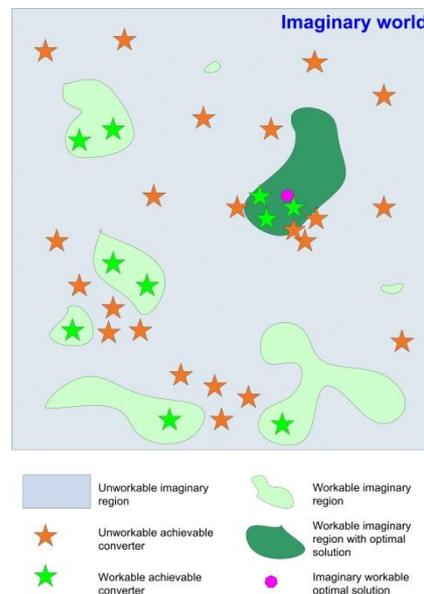


Figure 1: Imaginary world illustration

DISCRETIZATION PROCESS PROPOSAL: APPLICATION TO AN INTERLEAVED BUCK CONVERTER

Discretization Process Proposal

As the designer has already spent time modeling for designing in the imaginary world and find the optimal imaginary workable solution, he probably won't have enough time left to perform discrete optimization among all the workable achievable solutions. He will then perform discrete optimization only on the local workable

imaginary region, closest to the optimal imaginary solution (Figure 1). It may be not the optimal discrete solution as the optimal workable achievable one could be located in another workable imaginary region but at least the designer believes in it since he has already validated it!

We therefore propose the following heuristic discretization process. Based on the optimal imaginary solution, we sequentially re-optimize in the imaginary world with the two discrete variables closest from the imaginary optimal one until no more discrete variables remain. The order of the variable to be discretized is chosen as a function of their influence on the objective function, the first variable being the one that impact the most the objective: in that approach, the knowledge and experience of the designer are essential to determine the judicious sequence.

Application to an Interleaved Buck Converter

An Interleaved Buck Converter is made of several Buck converters that are parallelized and phase shifted of $2\pi/Nb_{phases}$ (Figure 3). The discrete components are colored: in purple the number of phases, in green, the MOSFET and diode to be selected in the manufacturer catalog, in blue the input and output capacitors that have two discrete parameters: their numbers and their values to be selected off the shelf parts. In orange are the inductors that are made of a discrete number of turns and discrete parts as the core and the Litz wire to take again among catalogs. Finally there are 13 discrete design variables. The discretization process (Figure 2) has been applied on the IBC with the converter power density as the objective function to be maximized (Table 1). Of course the discrete converter has a lower power density than the imaginary one. But the losses and weight proportions are maintained.

CONCLUSION

The discretization process proposed in this paper has some defaults like a local research area, a risk of oversizing (the combination of the discrete variables may not be optimal), etc. But it still has some non-negligible advantages such as its simplicity to put in practice even for power electronics designer, its computation time and giving a discrete solution close to the imaginary one.

REFERENCES

- [1] C. Berliner and J. A. Brimson, *Cost Management for Today's Advanced Manufacturing: The CAM-I Conceptual Design*. Harvard Business School Press, 1988.
- [2] M. Delhommais and F. Wurtz, "Optimization Process To Use Non-Derivable Model in a First Order Optimization Problem," in *14th International Workshop on Optimization and Inverse Problems in Electromagnetism*, 2016, pp. 3–4.

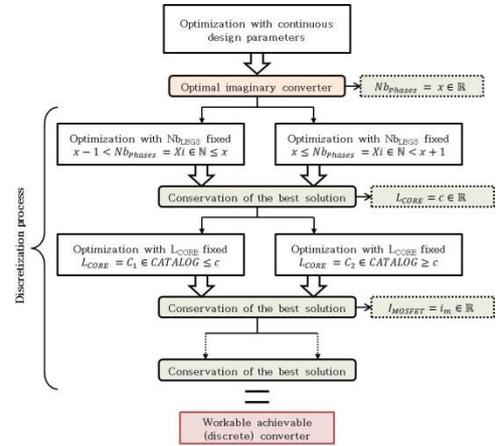


Figure 2: Discretization process of the IBC

(Figure 3). The discrete components are colored:

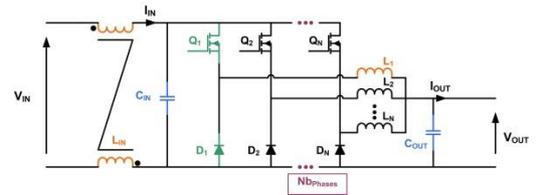


Figure 3: Interleaved Buck Converter to design

Table 1: Discretization process applied on an IBC: comparison between imaginary and real converter

		Imaginary converter	Discrete converter
<i>Design time</i>		15 minutes	8 times 15 min ~ 2h
<i>Iteration number</i>		43 iterations	
<i>Power density</i>		10 kW/kg	8.08 kW/kg
<i>Number of IBC phases</i>		2.6	3
<i>Power inductances</i>	weight ratio on IBC weight	26 %	34 %
	losses ratio on total losses	34.8 %	34 %
<i>Active components</i>	losses ratio on total losses	65.6 %	66 %
<i>Filtering</i>	Filter weight	13.4 %	14.3 %