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Modeling Strategy for Designing in the Continuous Imaginary World with Power Electronics Discrete Components

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Abstract. During the preliminary design sketch phase of power electronics systems, it may be interesting to use gradient based optimization algorithm with continuous and differentiable models. In this paper, we propose to power electronics designers a modeling strategy for designing in the continuous imaginary world with the discrete components.

Keywords: 1st order optimization, switching cell, continuous modeling, imaginary world

INTRODUCTION

In the early step of a design process, the degree of freedom is large for the designer [1]. In the aim to enjoy this fact we propose to use gradient based optimization method [2], [3], [4] named 1st order optimization method. But this method requires having continuous and differentiable models. Unfortunately in the specific domain of static power converters that are made of discrete variables, using such method can be a challenge for the designer. In this paper, we will first describe more precisely what is the nature of the discrete variables in power electronics and the concept of designing in the imaginary world. Then we propose a strategy that helps the designer to take this challenge up. It will be illustrated by the model of a switching cell for a Buck converter.

NATURE OF THE DIFFERENT VARIABLES IN POWER ELECTRONICS & DESIGN IN THE IMAGINARY WORLD CONCEPT

A power static converter is made of electronic components that are gathered in accordance with the converter topology itself and its needs (measures, etc.) to work under certain control. It is then possible to define two classes of design variables: the hashed variables and the distinct variables. The hashed variables are the physically continuous but industrially discretized as for the electronic components (transistors, capacitors, wires, etc.). The distinct variables are the physically discrete variables as for the topology, the switching and the technology choice.

Usually power electronics designer directly design the power converter with the discrete components, topologies and technologies but succeed to obtain the average behavior of the converter. They are finally designing in the “real world”. To apply the gradient based optimization algorithm, all design variables should be continuous even if they do not actually exist in the real world. That is what we call “design in the imaginary world”. The next question is then: how to get continuous design variables? In the paper we focus on the hashed variables modeling strategy when the distinct variables have been treated in other papers [3].

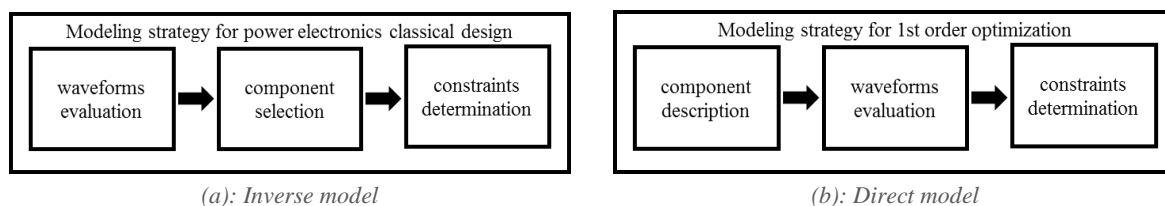


Figure 1: Modeling strategies (a) for converter classical design method, (b) for 1st order design by optimization method

MODELING STRATEGIES FOR THE DISCRETE HASHED VARIABLES

Modeling strategy for a classical design illustrated by a switching cell

It is common that power electronic designers try to define the component specifications based on its working electromagnetic waveforms (Figure 1.(a)). For example, in a classical design the engineer will choose the switching cell components that are the MOSFET and diode in a catalog based on the maximum voltage and RMS current that flow into them and on the voltage and current rates that the manufacturer indicates. Then, he will determine the thermal and efficiency constraints (Figure 2. (a)).

Modeling strategy for a design in the continuous imaginary world illustrated by a switching cell

The proposed strategy helps power electronic engineers to create a continuous and differentiable model of the converter for 1st order optimization method. The designer should start with the component description, then with the evaluation of the electromagnetic waveforms and finally with the computation of the constraints (Figure 1.(b)). For example with the switching cell devices selection: since their behavior is linked to their die area (i.e. their current rate) it is possible to directly compute their constraints regarding this design parameter. All static and dynamic parameters of these devices are linked to it, so it has been possible to interpolate the manufacturer datasheets (Figure 3). Thanks to these parameters it is then possible to define the switching waveforms and so the device losses. With these losses and the thermal parameters of the devices, it is finally possible to get the device junction temperatures (constraint) thanks to a simple thermal model (Figure 2.(b)).

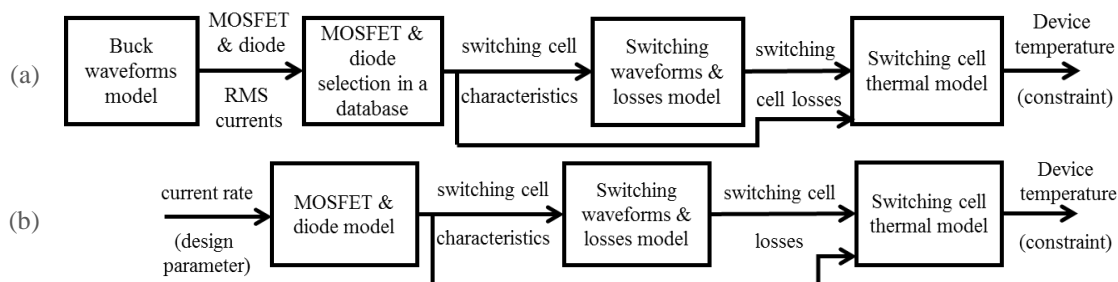


Figure 2: Switching Cell modeling (a) in classical design, (b) in 1st order optimization

CONCLUSIONS

In this paper, we offered a strategy that helps the power electronics designer to get easily and without too many efforts a continuous model of the converter despite the discrete components. It has been illustrated with a switching cell.

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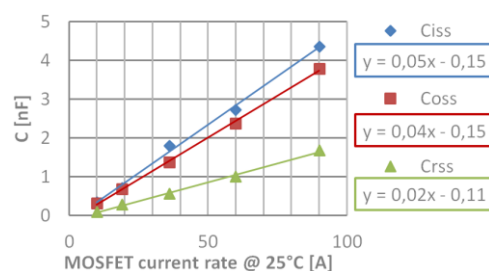


Figure 3: parameters interpolation