A Parameterization Tool for Power Electronics Design at System level

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Abstract

This paper describes a parameterization software used for the generation of behavioral models of power converters. This tool eases the capture and generation of fast and accurate models based on the information provided by manufacturers and measures. The models incorporate many behavioral features and can be used at different levels in the analysis, design and verification of complete power distribution systems like aircraft and automotive power systems. Simulations of common tests of power systems are presented to show the functionality of the models.

1. Introduction

In the analysis, design and verification of power distribution systems, simulation is a decisive tool in order to assure its overall performance and reliability.

The needs of power converters simulations are different from the power systems simulations needs. When simulating a converter, for example a buck, the information that the designer wants to get from its model is a more detailed behavior of each current and voltage in the circuit. The fact of knowing all this information costs simulation time. When designing power systems, the use of detailed models for each component does not provide any advantage because most of the information is useless and the simulation time increases prohibitively. To avoid this, abstract models can be used at expenses of a little accuracy, obtaining a significant improvement in simulation time.

In power systems design it is common to use commercial converters because the manufacturer assures the converter performance over a range, this eases the implementation of the system, but the use of these converters has some disadvantages when the system must be fully validated in simulation before its construction. Some of these disadvantages are:

- The lack of simulation models for each DC/DC converter.
- The lack of information about the converter structure to develop the models
- Even if all the information is provided, the developing of a model using traditional methods like averaging is not a trivial task.
- In addition, a model must be generated for each converter in the system.

The software described in this paper eases the development of simulation models of power converters, providing a friendly interface to capture the converter data and quickly generate the necessary models to validate the power system.

The characteristics of the models are as follows:
- Behavioral models independent of the structure of the real converter.
- Generated based on the information provided by manufacturers in datasheets and in measures of common essays.
- Generated according to the user requirements for each test.
- Optimized for speed in simulation.
- Implemented in VHDL-AMS for exchangeability.

The model used in the parameterization tool for the DC/DC converter is based on the model presented in [1].

The basic model that is generated is a static DC/DC converter; this model is a simple but fully functional converter. Over this basic model many other features can be added depending on the user requirements as show in figure 1. Some of these features are:

- Dynamic behavior
- Thermal behavior
- Protections
- Multiple outputs
- Cross regulation
- Current share
- Remote control

The software is designed with a friendly user-interface and each feature can be added or removed in a simple way.
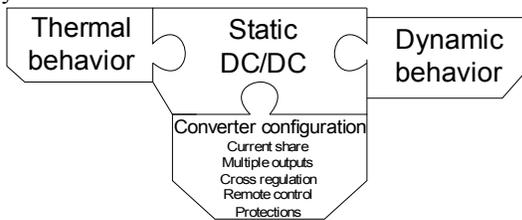

Figure 1. DC/DC converter features

2. What a simulation tool should provide to aid the system designer?

To evaluate the performance of a power system it is necessary that the models allow the obtaining of the following information when simulating the complete system

- Efficiency
- Transient responses
- Temperature calculation
- Failures
- Stability

2.1. Efficiency

In order to generate a static DC/DC converter a few parameters need to be captured like the input and output voltage, and the output type (regulated or not). The efficiency curve of the converter is set with an interactive control that allows specifying a curve based in points. Figure 2 shows a screen capture of the software, can be seen the tab where the general parameters of the converter like the efficiency curve and thermal model are captured. The static model can be used for tests like operation point or for other steady state analysis
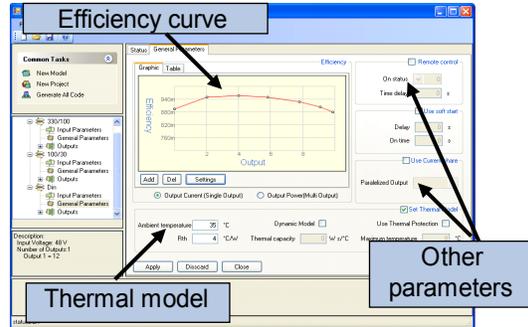

Figure 2. Screen capture of general parameters tab.

The static DC/DC automatically calculates, without placing any other element in the sheet, common measures like input and output power, efficiency, input and output currents and voltages. With this information for each converter the total system efficiency can be easily calculated.
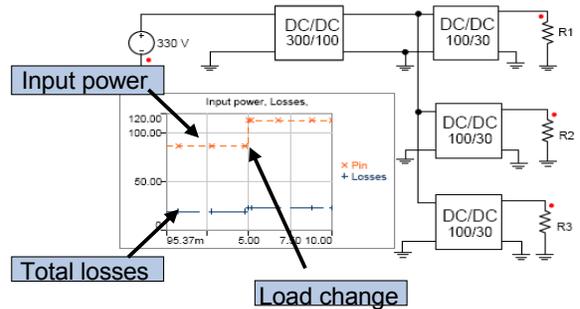

Figure 3. Calculating the looses in a system for different loads

The figure 3 shows a system formed by one converter that reduces the voltage from 330 to 100 to feed a 100 V bus in which are connected three converters of 30 V. In this test the total losses for two points are calculated, in the graphic are shown the input power provided by the battery and the total losses in the four converters, at five seconds a load change occurs.

2.2. Transient responses

Dynamic responses can be specified with interactive controls that were designed to quickly capture the data giving the possibility to view graphically and numerically the modeled response, a screen capture is in figure 4. In the graphic view, parameter points can be dragged to represent the desired behavior and the parameters can be set directly in the numerical view. The modeled features are:

- Input dynamic (Inrush current): This feature is used to model the input current due to the input capacitors when the converter is powered.
- Output dynamic (Output regulation): this feature is used to model the transient response when a load step occurs.
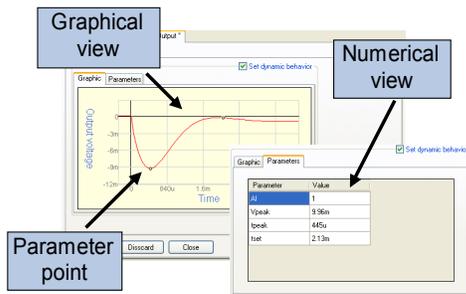

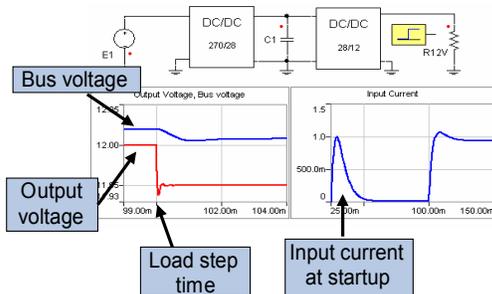*Figure 4. Dynamic response capture, graphical and numerical view.*

Figure 5.Output voltage and bus transient response, Inrush current.

In the figure 5 it is shown a two converter system with an intermediate 28 V bus. The input current at startup of the 12 V converter is shown in figure. A load step is applied to the 12 V converter at 100 ms; its effects on the output voltage and bus voltage can bee seen.

2.3. Temperature calculation

The thermal behavior is another point of interest. The temperature of the converter is calculated with the power dissipation of the converter and the thermal resistivity value from datasheets. The heating of the converter can be modeled as static or dynamic. The dynamic model simulates the gradual heating of the converter. In the example of figure 6 it is presented a simulation of both models for the same power dissipation. The dynamic model rises from ambient temperature (35ºC) to 40 ºC in 80 seconds; the static model calculates the steady state temperature for each point.
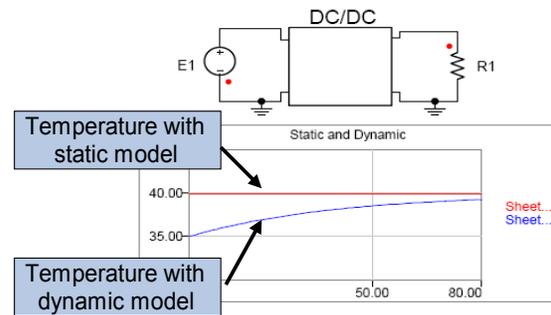

Figure 6.Static and dynamic thermal model simulation for the same power dissipation.

2.4. Fail tests

The model can incorporate the protections of the real DC/DC converter in order to simulate the converter response under real conditions. The simulated protections are:

- Input Under-voltage and Over-voltage turn on and turn off.
- Output over-voltage
- Over temperature.
- Over current

Other kinds of failures can occur as simulation in figure 7 illustrates. In the example there are three parallelized converters (with current share option) and at 80 ms one of them fails; the other two converters provide the necessary current.
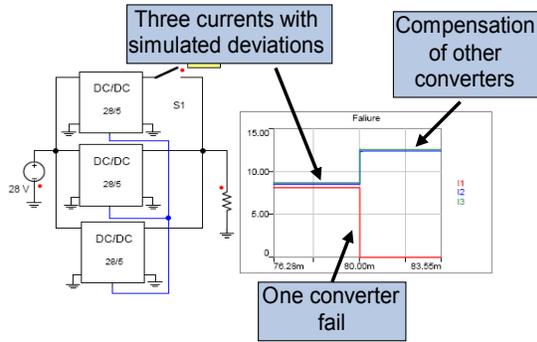
Figure 7.Paralelized converters failure simulation.

As shown in this example it is not only necessary to detect a failure, but also to verify if the system is able to overcome the failure.

2.5. Stability

In all the above examples, systems with only a few converters have been shown. In real systems there are other components like filters, PFCs, etc. Even when each individual converter is stable, in conjunction with the other components the system may be unstable or can present undesired dynamic.
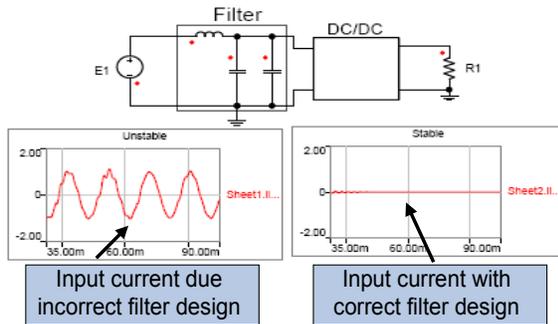

Figure 8.Stability verification, a correct and incorrect filter design.

This example in figure 8 shows a converter with a filter. In the first graphic the filter is an incorrect design that makes the input current to oscillate for a long time; the second graphic is a correct design.

The last example is a complete system that could be an aircraft distribution scheme figure 9. This system has eight converters with different characteristics. This system was simulated using almost all features of the software presented. The models were generated in less than one hour, and the simulation time for this complete system producing load changes, failures and other interactions takes less than 15 seconds for 100ms.
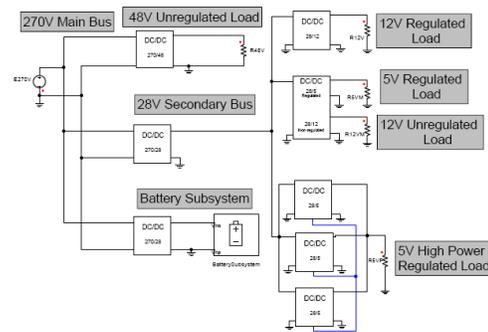

Figure 9. A complete aircraft power distribution system.

3. Conclusions

Parameterization software for generating behavioral DC/DC converters based on the manufacturer information and measures has been developed and presented. This software provides a friendly interface that reduces drastically the time to generate configurable models that fits most of commercial DC/DC converters. The models are optimized and can be used to validate complete power systems and provide information like efficiency, transient response, heating, failures and stability in a short simulation time.

4. References

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