PLECS

DEMO MODEL

Phase Shift DC-DC Converter with Integrated Magnetics

Last updated in PLECS 4.3.1
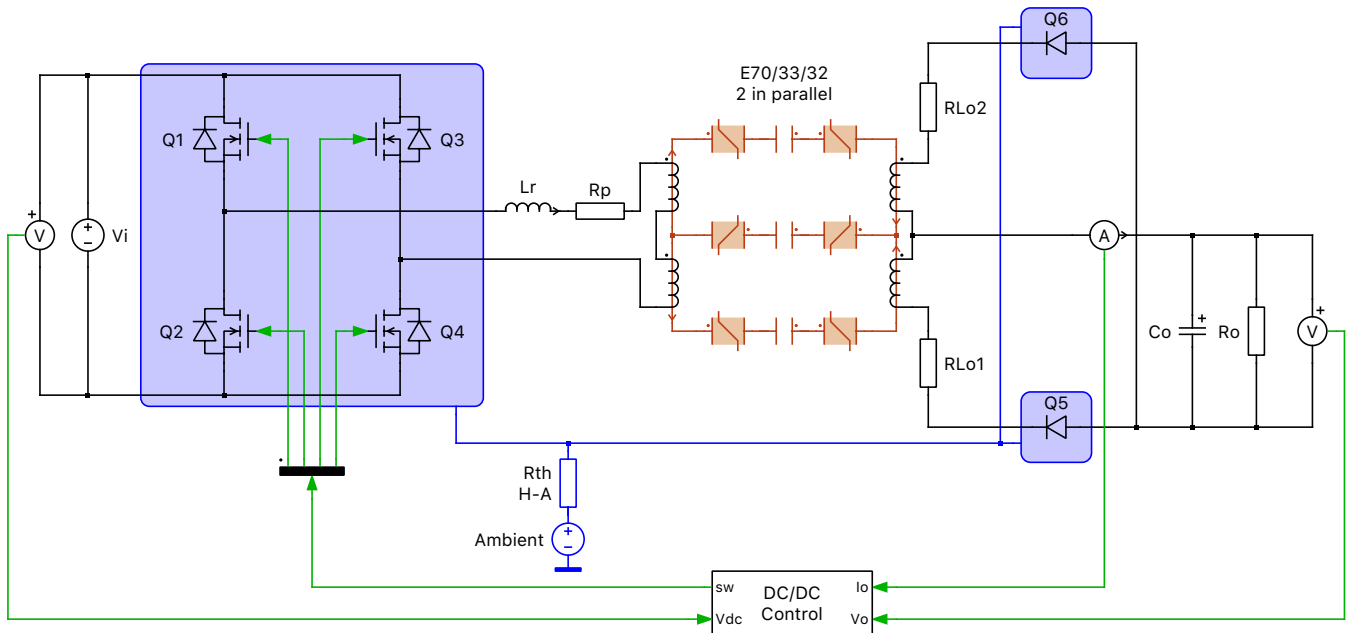
1 Overview

This demonstration shows a phase shift DC-DC converter with a magnetically integrated current doubler. The combined transformer and output inductors are implemented in the PLECS Magnetic Domain.

2 Model

Figure 1: Phase shift converter

Note This model contains model initialization commands that are accessible from:

PLECS Standalone: The menu **Simulation + Simulation Parameters... + Initializations**

PLECS Blockset: Right click in the **Simulink model window + Model Properties + Callbacks + InitFcn***

3 Model

This model shows a full bridge phase shift converter with a current doubler at the output. A stiff 400 VDC voltage source at the input represents the rectified utility. A transformer provides galvanic isolation, while the transformer windings ratio is chosen to provide 48-50 VDC at the output. The current doubler rectifier is implemented by providing the output current two paths across separate branches containing an output inductor and diode. To reduce the overall size of the magnetic components, the transformer and filter inductors may share the same core. Due to the phase shift modulation, zero-voltage switching (ZVS) can be achieved, which reduces the turn-on losses of the MOSFETS to zero.

3.1 Control

Each switch in the full bridge is on for 50% of its respective switching period. The switch pairs in the two legs all have the same switching period but are operated such that between each switch a phase shift is introduced that varies a small amount over time based on a dynamically calculated modulation index using feedback measurements. An output voltage error signal is generated based on a setpoint value and this is fed through a PI regulator to generate an output current setpoint. The difference between output current setpoint and the measured value is fed into the current controller, which has a simple proportional gain, and generates the phase shift ratio for the PWM modulator.

3.2 Magnetic Circuit

The motivation to integrate the output inductors into the transformer core is to increase the power density of the converter. Modeling such a magnetic geometry using an electrical equivalent circuit with coupled inductances can be cumbersome. Using the PLECS Magnetic Domain, however, modeling such a structure becomes intuitive and simple. The parameters of the magnetic model are directly related to the geometry and material characteristics of the core, which in most cases can be obtained from datasheets.

In this model two E 70/33/32 cores from TDK using N87 material are stacked.

3.3 Thermal Model

A thermal description is assigned to all four of the MOSFET switches in the full bridge as well as the output diodes. These descriptions can be viewed and edited by double-clicking on the component and selecting **Edit...** from the drop-down menu of the **Thermal description** parameter. The thermal parameters were obtained from datasheets provided by Infineon, specifically for the IPW60R280P6 Cool-MOS superjunction MOSFET and IDW75E60 Si power diode. For the two different device types, the thermal impedance chain representing the thermal transitions from the junction to the case are entered directly in the thermal descriptions.

Also note that the MOSFET model was customized to permit modeling multiple devices connected in series and parallel. The number of parallel or series connections can be configured in the parameter window of the MOSFETs. An equal distribution of current and voltage in both parallel- or series-connected MOSFETs is assumed. The thermal parameters are automatically scaled to reflect the number of devices and their configuration.

Since the three heat sink components are connected together, all six devices dissipate heat into the same heat sink. A thermal resistance connects the heat sink with the temperature of the ambient air. The thermal descriptions for the MOSFETs and diodes are stored in a private thermal library in the directory `/phase_shift_dcdc_converter_with_integrated_magnetics_plecs`.

4 Simulation

Run the simulation with the model as provided to view the output signals, the losses and junction temperature for Q1, and the BH curve of the magnetic core.

4.1 Steady-State Operation

The final temperature of the junction for Q1 can be calculated with the Steady-State Analysis that is pre-configured in the model. For PLECS Standalone or Blockset (in Simulink) execute the following steps:

- *Standalone:* From the **Simulation** menu choose **Analysis tools...**. This opens a dialog, in which the analysis has already been pre-configured. To start the analysis, click on the **Start analysis** button. You can display the progress of the analysis by clicking on the **Show log** button.

- *Blockset:* Double-click on the Steady-State Analysis block to open the dialog and click on the **Start analysis** button. The progress of the analysis is displayed in the MATLAB Command Window.

When the analysis has finished a simulation of five steady-state cycles is displayed for all waveforms preconfigured in the Scopes.

5   Conclusion

This model discusses the operation of a phase shift DC-DC converter, with both thermal and magnetic circuits included. In addition to a startup transient simulation, a Steady-State Analysis is also configured to quickly determine the final operating temperatures of the devices.

References

[1] U. Badstuebner, J. Biela, B. Faessler, D. Hoesli and J.W. Kolar, "An Optimized 5 kW, 147 W/in^3 Telecom Phase-Shift DC-DC Converter with Magnetically Integrated Current Doubler," Applied Power Electronics Conference and Exposition (APEC), 2009, Twenty-Seventh Annual IEEE, pp. 21-27, 15-19 Feb. 2009.

Revision History:

PLECS 4.3.1   First release

How to Contact Plexim:

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