PLECS

DEMO MODEL

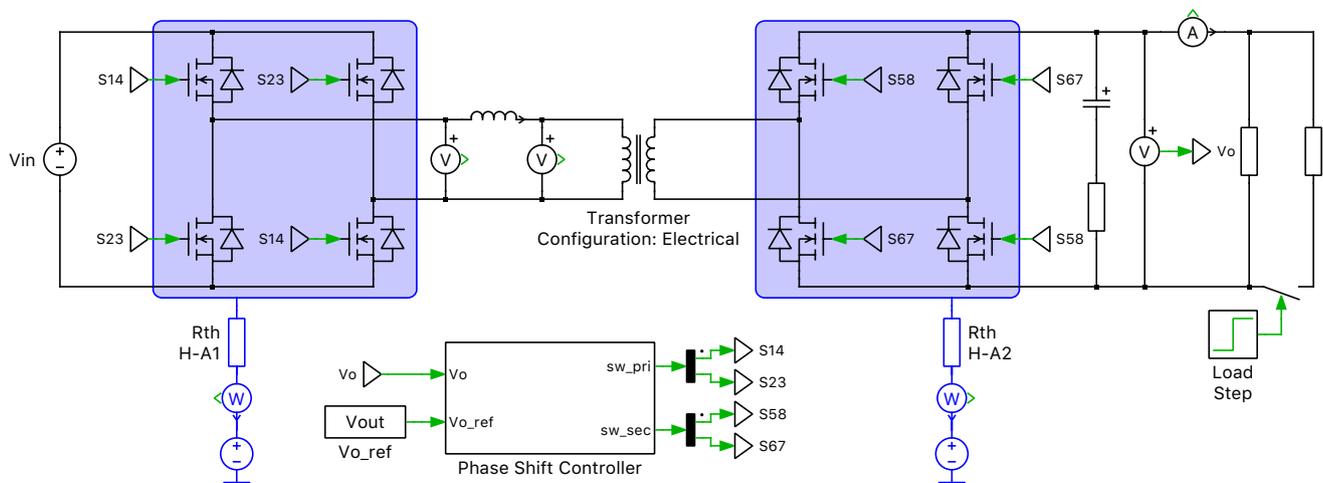**Dual Active Bridge**

Last updated in PLECS 4.3.1

1 Overview

This demonstration shows a dual active bridge (DAB) converter. A DAB is a bidirectional DC-DC converter with identical primary and secondary side full-bridges, a high frequency transformer, an energy transfer inductor and DC-link capacitors. The system specifications here are an input voltage of 95 VDC, an output voltage of 380 VDC, and a switching frequency of 250 kHz. This model contains a transformer that is implemented in two configurations: as an ideal model and a more detailed version that includes saturation behavior that we modeled using the PLECS magnetic domain. Additionally, we included the thermal behavior of Wolfspeed C3M0030090K and C3M0065090D Silicon Carbide MOSFETs for the primary and secondary side bridges, respectively, using the PLECS thermal domain. After a system startup transient settles, a load step change from 1 kW to 2 kW is simulated.

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***

2 Model

Figure 1: Dual active bridge converter

The two legs of both full-bridges are driven with complimentary square-wave pulses. Power flow in the dual active bridge can be directed by phase-shifting the pulses of one bridge with respect to the other using phase shift modulation. The control directs power between the two DC buses such that the leading bridge delivers power to the lagging bridge. The applied square waves to the bridges create a voltage differential across the energy transfer inductance and direct its stored energy. Energy transfer inductance in the model refers to the leakage inductance of the transformer plus any necessary external energy transfer inductance.

In ideal cases with dual active bridge converters, zero voltage switching (ZVS) can be realized when the voltage transfer ratio (M) across the transformer is equal to 1:

$$M = \frac{V_{\text{out}}}{V_{\text{in}}}$$

where, n is the transformer turn ratio, V_{out} is the output voltage and V_{in} is the input voltage.

In non-ideal cases, ZVS depends on the resonant relationship between the output capacitance across each device and the equivalent inductance of the circuit during different switching intervals. During switching events, the current through one of the complimentary devices is interrupted, but due to the energy transfer inductance, current is supplied through the output capacitor and forced through the anti-parallel diode of the device [1].

The simulation parameters used for developing this model have been obtained from the attached reference [1].

2.1 Control

Each switch is on for 50% of its respective switching period. The switch pairs in the two bridges all have the same switching period but are operated such that between each bridge a phase shift is introduced that varies based on the modulation derived from feedback measurements. An output voltage error signal is generated based on a set point value and this is fed through a digital PI regulator to generate the phase shift ratio for the PWM modulator.
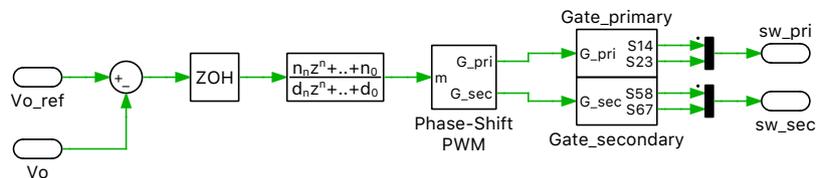
Figure 2: Phase shift controller

2.2 Thermal Model

A thermal description for Wolfspeed's C3M0030090K SiC MOSFET is assigned to all four of the primary side semiconductor switches and Wolfspeed's C3M0065090D SiC MOSFET is assigned to all four of the secondary side semiconductor switches. 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 descriptions have been obtained from the Wolfspeed website. The MOSFET model here exhibits a synchronous rectification effect.

Two Heat Sink components capture the heat dissipated from the bridges. A thermal resistance connects the Heat Sink with the temperature of the ambient air. The thermal descriptions for the MOSFETs are stored in a private thermal library in the directory /dual_active_bridge_converter_plecs.

2.3 Magnetic Model

The transformer model is implemented using a Configurable Subsystem component. It can be configured as an ideal transformer for speeding up the simulation or as a more detailed transformer model that includes saturation behavior. For the detailed version, Payton Planar Magnetics' T250-4-16 transformer is modeled using the PLECS magnetic domain. 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. The transformer uses industry standard E43/28 core and TP4A ferrite material from TDG [2].

3 Simulation

The simulation shows two load conditions with different power outputs. At the start of the simulation, the output power drawn by the load is 1 kW. At 0.4 s, the load step changes the output power drawn

to 2 kW. The scopes display the output signals of the primary and the secondary sides, the losses and junction temperature of the switches S1 and S5.

An XY Plot component shows the BH loop for the saturation effect of the core. Using the material datasheet [2], it is decided to not operate the core beyond 0.51 T and the XY plot shows that the core is driven close to this value without exceeding it.

References

[1] George, Kenny, "Design and Control of a Bidirectional Dual Active Bridge DC-DC Converter to Interface Solar, Battery Storage, and Grid-Tied Inverters" (2015). Electrical Engineering Undergraduate Honors Theses. 45. Click to access online: Kenny George's thesis.

[2] Datasheet for "TP4A". Click to access online: TDG's TP4A material datasheet.

Revision History:

PLECS 4.3.1   First release

How to Contact Plexim:

PLECS Demo Model