Behavioral Modeling of Power Semiconductors in Modelica

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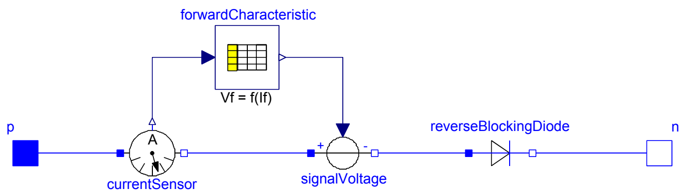
The paper introduces behavioral (macro) models of power semiconductors, i.e. diodes, MOSFETs and IGBTs, being part of a library for simulating power electronics utilized, e.g. in electrified powertrains of either hybrid electric vehicles (HEV) or purely battery electric vehicles (BEV). The models consider static, dynamic (switching mode) and thermal effects and in most cases can be fully parameterized solely on the basis of characteristic curves and parameters specified in datasheets. The main purpose of behavioral models is an accurate representation of the semiconductor signals to, e.g. calculate the overall losses. To this end the component's behavior is described via characteristic curves and parameters provided in datasheets.

In the simplest case, the static model of a diode can be described as depicted in the figure below. The current through the diode is measured using a current sensor and serves



as input signal to a table which stores the forward characteristic $V_f = f(I_f)$ specified in the datasheet. The corresponding forward voltage drop is fed into a signal-controlled voltage source. The additional ideal reverse blocking diode ensures that the current solely flows in forward direction. Thus, on the one hand behavioral models of, e.g. diodes and MOSFETs can be parameterized solely on the basis of datasheets and on the other hand, the models behave as specified by the manufacturer under nominal conditions. In case of IGBTs due to their internal semiconductor structure, the occurring tail current has to be measured in advance. Moreover, in trench/field-stop IGBTs due to the additional field-stop layer added to the semiconductor structure the model developed in [1] is not valid anymore and has to be modified.

The MOSFET models are verified in simulations with various test circuits and are validated with measurement data provided by a company developing electric drive systems.

Since behavioral models provide detailed switching slopes, the simulation performance is totally unacceptable if such models are used to simulate, e.g. the driving range of an electric vehicle. The arising numerical problems are discussed and possible solutions are provided on how to modify the models in order to use them in e.g. system simulation.

References

[1] Wintrich, Arendt: Verhaltensmodellierung von Leistungshalbleitern für den rechnergestützten Entwurf leistungselektronischer Schaltungen, Technische Universität Chemnitz, 1996.