Real-time simulation of power electronics systems using FPGA technology

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Context

Real-time simulation along with Hardware-In-the-Loop (HIL) technologies exist since many years ago and have been widely used lately for model validation and testing before the implementation of drives such as electrical machines, power electronics, electrochemical systems etc. Different from a classic simulation, real time simulation depends not only on the results of logical / arithmetic calculations of the model, but also on physical time (real time) when these results are produced. A hardware-in-the-Loop (HiL) application is a form of real-time simulation, the difference being given by the addition of real physical component in the loop.

Today, real-time simulation for power electronics applications (converters, inverters, power electronics components such as IGBT, GTO, etc.) is still a serious challenge. In a mathematical model, the power electronics components are characterized by their high switching frequency. This frequency can range from a few kHz (IGBTs, high power application) to some MHz (MOSFET, low power application). This causes problems if we want to simulate a mathematical model that contains many power electronics components in real time (switched power electronic systems can exhibit an almost infinite number of different modes of operation). To ensure the numerical stability of the model, the computation time step of the model should be much smaller than a cycle of switching time. Solve such a complex mathematical model while meeting the strict time constraint remains a great challenge, even with the growth of computing power of modern processors.

PhD Thesis subject:

The first aim of this PhD thesis is to develop a real time model of a complex power electronic system using FPGA technology, which take into account the transient during switching. Including the transient behavior into a real time model of power electronic systems is highly challenging due to:

1) the IGBT transient behavior is non-linear and the model solution requires numerical iterations which are time-consuming and thus limit the achievable time-step
2) the transient timescale of IGBT is very short especially for the medium/low power IGBTs in which less than 100 ns transients are of concerns, leading to the fact that the time-step should be small enough so as to be able to present correctly transient waveforms.

Furthermore, the physical nonlinear model of the power electronic system is represented by a Differential Algebraic Equations system (DAEs) of stiff type, which imposes many numerical problems known in the numerical solver algorithms (Euler, BDF, GEAR, etc.). Therefore, the second thesis objective is to develop a specific solver algorithm that can effectively solve the DAEs of the power electronic model in a very short time at each time step of numerical calculation. To reach this goal, the PhD candidate will explore the model implementation using parallel computation within FPGA.

References

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