Real-time simulation of the hybrid electric vehicle powertrains

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Context

Real-time simulation and Hardware-in-the-Loop (HIL) techniques emerge as indispensable tools in the design, modeling, testing and validation of electric vehicles (EVs) and hybrid electric vehicles (HEVs) powertrains, in order to reduce the cost and time to market. 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 Power hardware-in-the-Loop (PHIL) application is a form of real-time simulation, the difference being given by the addition of real physical power components in the loop.

Today, high accuracy real-time simulation and PHIL of new generation of electric powertrains is still a great challenge. Usually, an electric powertrain (EV or HEV) is composed by three main parts: energy source (i.e batteries, etc.), power conversion components (power electronics) and load (i.e motor, auxiliaries). The real time simulation of these electric drivetrains components involves complex physical modeling problems and the challenge of overall system integration.

Energy source and load models are highly non-linear, and usually coupled with different physical domains, which make the real-time simulation hard to be realized. The model complexity lead to significantly increased computation requirements and it might fail to run in real-time. In addition, multi-physical models consider the different internal dynamics, which can be very different from one physical domain to the other (e.g. fast fluidic dynamics vs. slow evolution of the temperature in energy sources), which can cause numerical model stiffness issues and lead to the real-time simulation overrun or even instable. Therefore, regarding the real-time simulation performance of energy source and load models, the balance between modelling accuracy, robustness and real-time simulation capacity need to be carefully considered.

On the other hand, modern power electronics components models are characterized by their high switching frequency and on-off characteristics. The switching frequency can range from a few kHz to some MHz. Mathematical models that contain a number of power electronics components can lead to serious real time simulation problems (e.g. limited simulation time step size, large memory to store circuit topology due to on-off states of power switches, etc.). 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 requires the development of specific real time simulation techniques as well.

PhD Thesis subject:

The aim of this PhD thesis is to develop real time models of different components in a hybrid electric vehicle powertrain and integrate them in an advance electric vehicle real time simulation platform. Each component of the electric powertrain has its unique characteristics, attributes, and other complexities, and they must be considered in the real time models. The PhD student will bring to develop specific and optimized numerical solving algorithms for models of energy sources, power converters and loads, using FPGA technology and parallel computation.

References

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