Behavioural Modelling of an Hybrid Car Using the System Simulator Portunus.

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Behavioural modelling of an hybrid car shows the benefits designers can derive from using a system simulator. Using a comprehensive environment such as that provided by Portunus allows the designer to build a complete model which includes the mechanical and electrical part of the system, but also command laws, motor drives and system management thanks to block diagrams and state machines.

The Toyota Prius II is a challenging subject as it involves a complex serial/parallel hybridisation strategy designed to optimize the system in order to obtain optimal performance in terms of consumption and energy laws.
This hybrid system is mainly composed of an internal combustion engine (ICE), two electrical machines – motor / generator – with different sizes and powers, all connected mechanically by a planetary gear. The two electrical machines are connected to a power battery through a power control unit which contains an inverter for DC / AC conversion and a boost converter which can increase the voltage from the battery up to 500V to meet the system's power requirements. The hybrid system allows the vehicle to operate in different modes such as start / stop, full electrical mode, regenerative breaking, sudden acceleration with maximum ICE efficiency, and normal driving where the ICE runs with an optimum torque / speed combination.

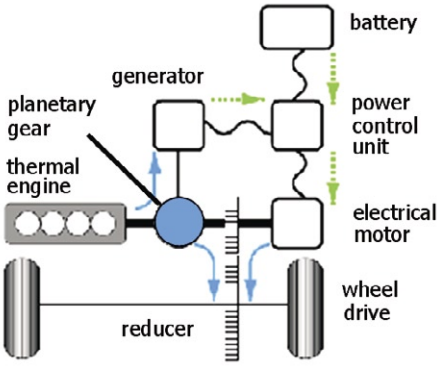

Fig. 1: Vehicle architecture (mechanical power flows according to blue arrows, electrical power according to green arrows).

Figure 2 presents the complete model built using Portunus. The mechanical equivalent network shown on the right-hand side, using built-in models (electrical machines, reducer, mass in translation, etc...) and user-defined models for the planetary gear and the wheel (using the software's C-Interface).

On the left of each electrical machine are the block diagrams used for speed regulation; and then the battery model which is linked to the boost converter.
Below is the state machine used to manage the whole system.

Among the many simulation results that can be obtained from this model, figure 3 shows battery charge trends (in red) throughout a complete speed cycle (in blue).

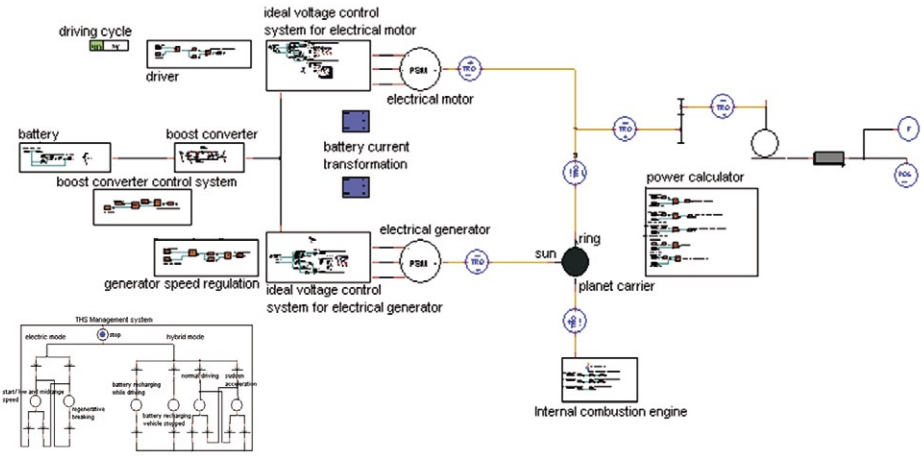

Fig. 2: Behavioural model of the Prius II car in Portunus.

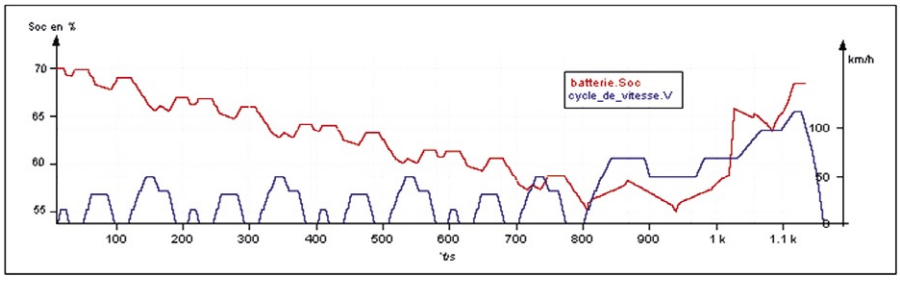

Fig. 3: Simulation results: driving cycle and battery state of charge.