PLECS

DEMO MODEL

Power Split Hybrid Vehicle System

Last updated in PLECS 4.4.2

1 Overview

This demonstration shows a Lithium-ion (Li-ion), battery-powered, series-parallel hybrid vehicle system. The simulation shows the startup for an electrically and mechanically coupled hybrid system.

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

2.1 Power Circuit

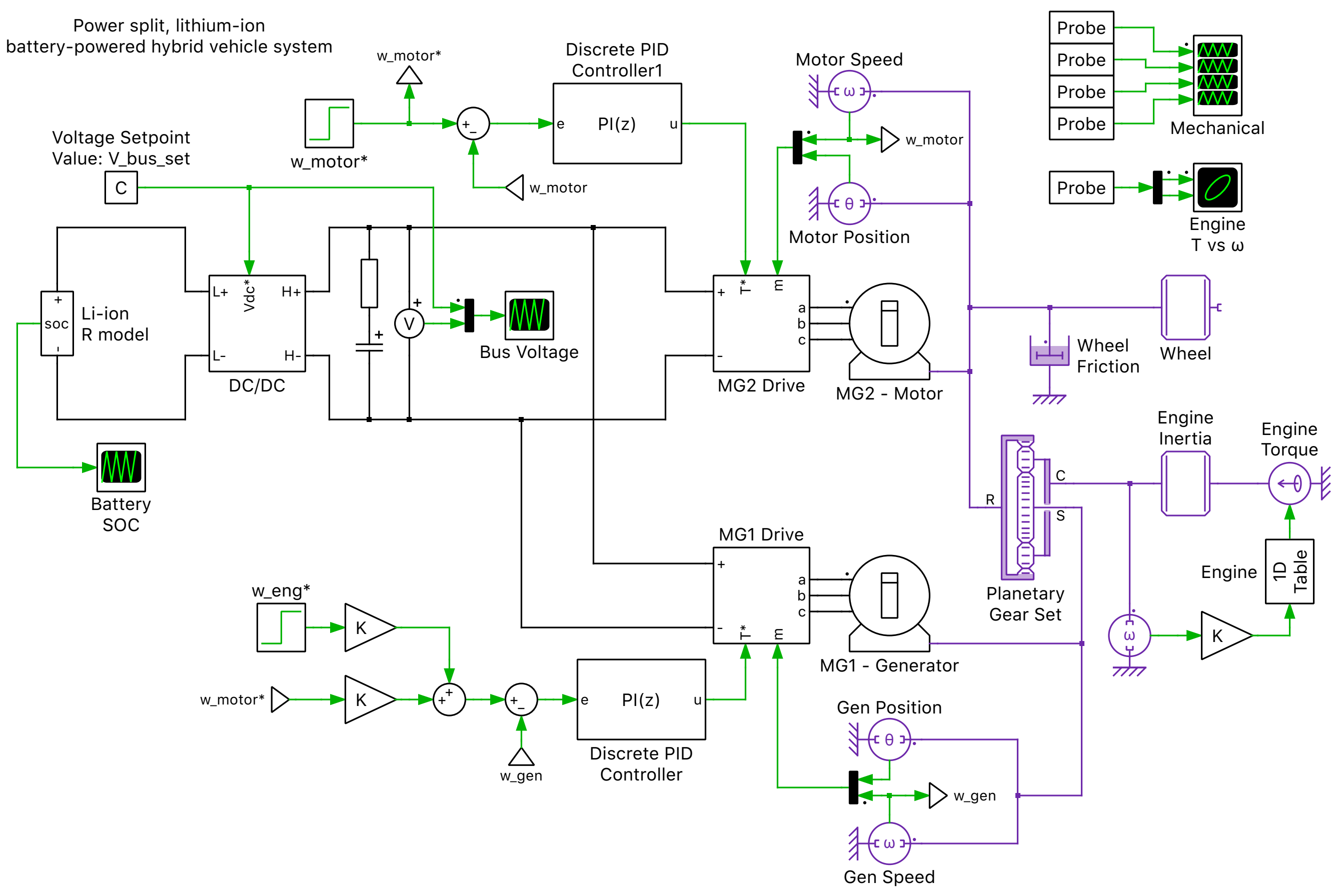

Figure 1: Overall system model

DC/DC converter

The electrical system of the series-parallel hybrid vehicle consists of a bi-directional DC/DC converter connecting the Li-ion battery to the DC-bus. The DC/DC converter and controls are identical to the system as described in the demo model "Boosted Motor Drive" in the PLECS demo models library.

The DC/DC converter is controlled to maintain the DC-bus voltage at 500 V using the battery.

Battery modeling

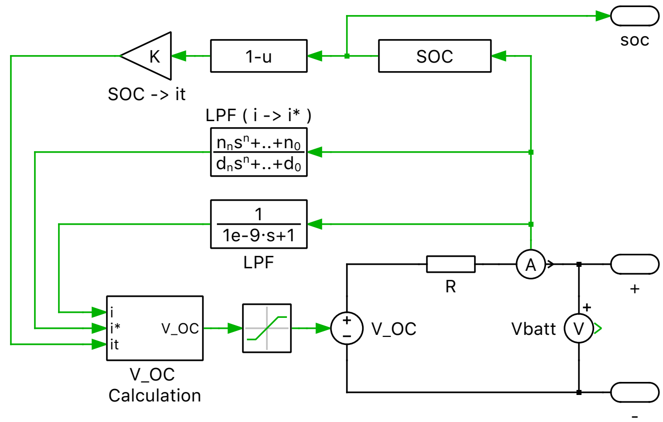

Figure 2: Battery subsystem

The Li-ion battery is based on a resistor-only electrical model proposed in [1]. This model enables users to take information from the battery datasheet to represent the current and voltage characteristics of a Li-ion battery pack as it is charged and discharged. The R-only model can be derived using three points on the V vs Charge curve. These are the voltage where the battery is fully charged, the voltage and charge where the exponential zone ends, and the voltage and charge where the nominal zone ends (see Fig. 1 in [1]).

Drive Systems

The series-parallel hybrid consists of two permanent-magnet synchronous machines (MG1 and MG2), inverters and associated controls. The DC-side of the inverters of both MG1 and MG2 are connected the DC-bus. MG2 is primarily used as a motor to aid the engine during acceleration. MG1 is used both as a motor and a generator. Both MG1 and MG2 system controllers consist of an outer speed loop and an inner current loop to regulate the rotor speed to a desired speed. The outer speed loop produces the torque setpoint for each machine. These torque set points are converted into dq-current set points. A digital synchronous frame regulator is used to regulate the current in each MG system. MG1 and MG2 are me-

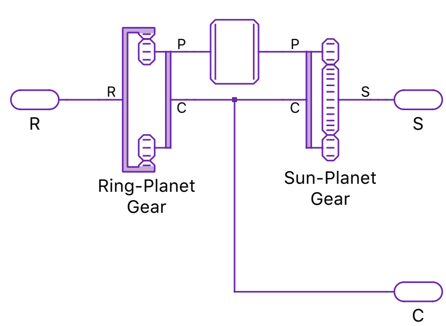

Figure 3: Planetary gearset subsystem

chanically coupled to the engine via a planetary gear set (PGS). The PGS module has three mechanical ports to connect it to the sun, ring, and carrier gears. The PLECS PGS module internally consists of a ring-planet gear and sun-planet gear implementation. This allows users to introduce non-idealities into the planet gear to observe the effects on the overall system.

The ring gear is connected to both the rotor shaft of MG2 and the wheel. The engine is connected to the carrier shaft and MG1 is connected to the sun gear. This configuration allows the engine and MG2 to provide the driving torque for the wheel, while MG1 is controlled to maintain the engine speed at the desired level.

A 1D look-up table is used to represent an engine operated to minimize the brake specific fuel consumption (BSFC). The data for the engine was obtained from Fig. 14 in [2].

3 Simulation

In this simulation, MG2 is used to accelerate the wheel from rest to a desired speed. MG1 is controlled to accelerate the engine speed at initially to about 125 rad/s (1200 rpm). At 70 ms, the desired engine speed is increased to about 188 rad/s (1800 rpm) while maintaining the same wheel speed. At 120 ms, the desired wheel speed is increased while the engine is maintained at 1800 rpm.

The motor torque along with speeds for MG1, MG2, and the engine are shown in Fig. 4. Energy is drawn

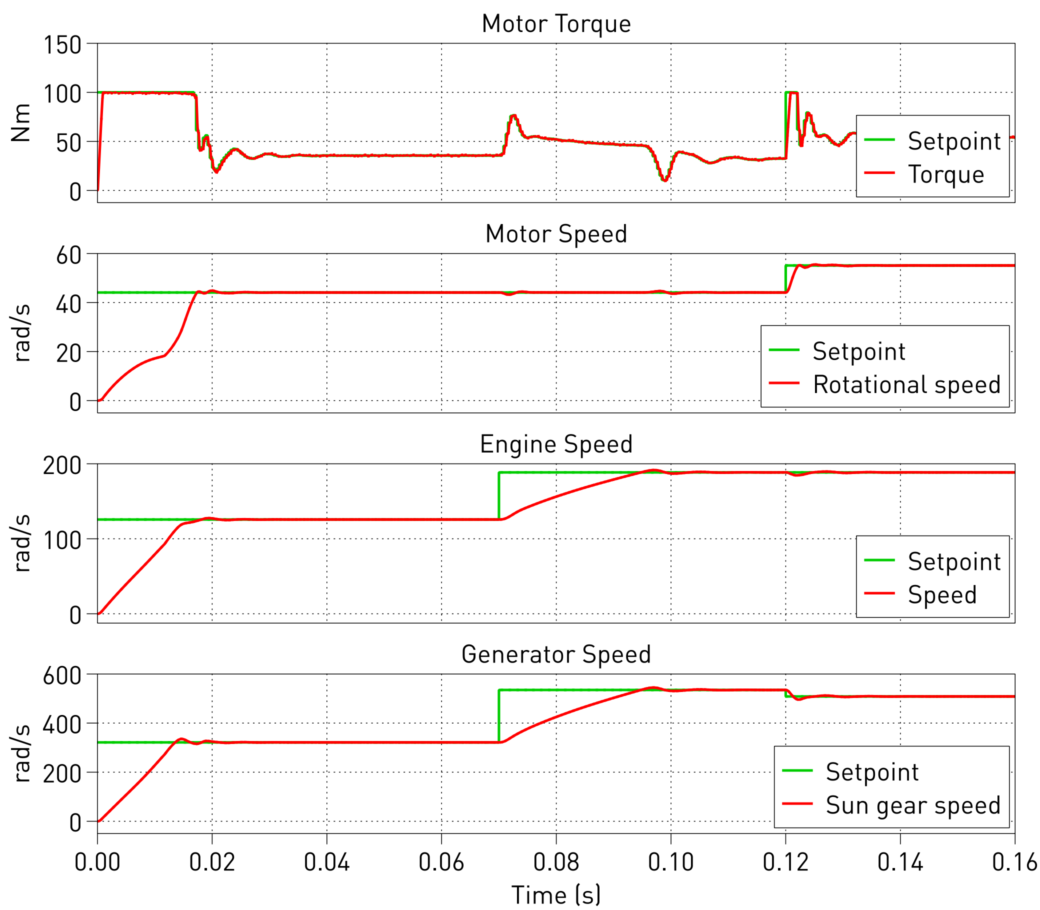

Figure 4: Mechanical waveforms

and stored in the battery to maintain the DC-bus voltage at the desired 500 V. The DC bus voltage is seen in Fig. 5. The Torque-Speed operating point of the engine is shown in Fig. 6. This represents the operation of the engine to minimize the BSFC in this simulation. As can be seen, the engine is not engaged below 850 rpm.

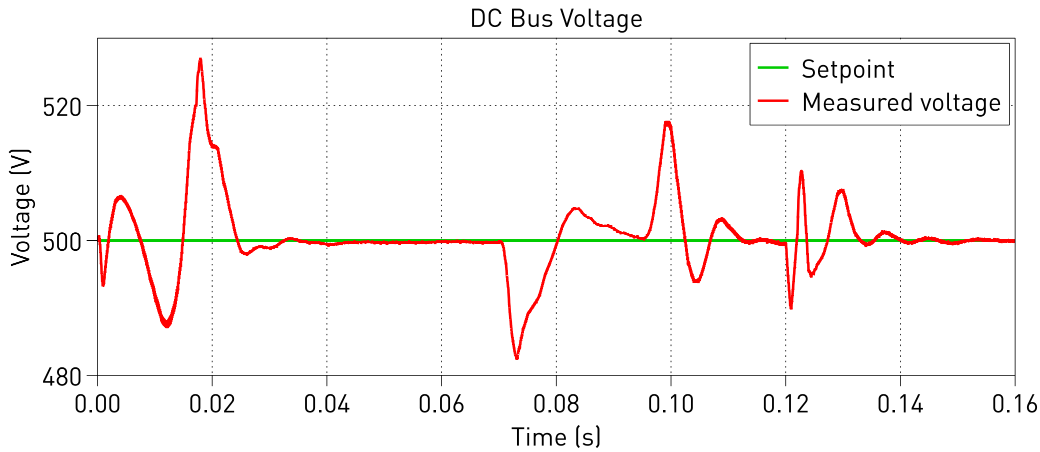

Figure 5: DC voltage

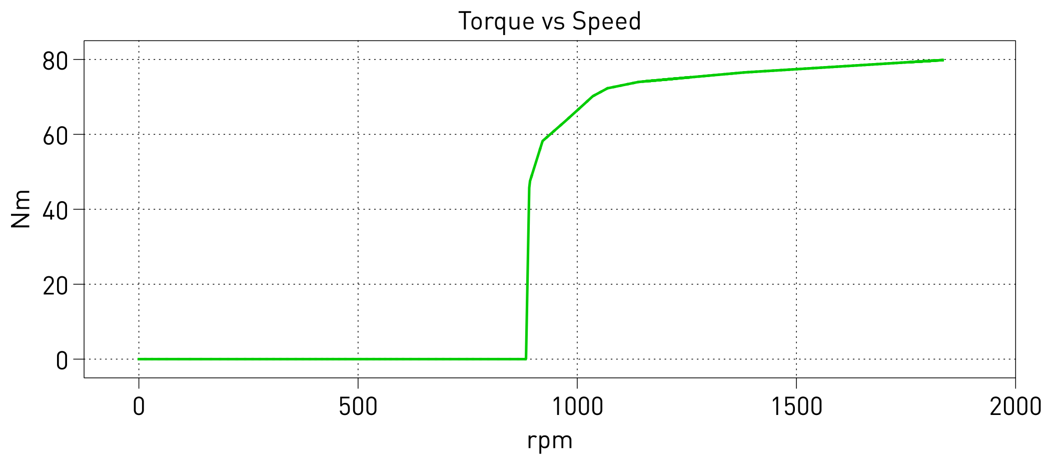

Figure 6: Torque-speed curve

References

[1] Tremblay, O., Dessaint, L.-A. "Experimental Validation of a Battery Dynamic Model for EV Applications." World Electric Vehicle Journal. Vol. 3 - ISSN 2032-6653 - Copyright 2009 AVERE, EVS24 Stavanger, Norway, May 13-16, 2009.

[2] Liu, J., Peng, H. "Modeling and Control of a Power-Split Hybrid Vehicle," in Control Systems Technology, IEEE Transactions on , vol.16, no.6, pp.1242-1251, Nov. 2008

Revision History:

PLECS 4.3.1	First release
PLECS 4.4.2	Update PI controller component

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