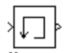
Battery system simulation in an EV drivetrain

The objectives in this model are to develop an EV system model in Simulink, which should follow the modeling and approaches applied in previous assignments, as follows:

1. Detailed model must be used for the battery system, which consists of identical cells that have the following parameters:
   - nominal capacity C_{nom} = 10 Ah,
   - The open-circuit cell voltage as a function of SOC is shown below, and is defined as a look-up table in **batt_V_SOC.mat**.
   - $R_o = R_o^+ = R_o^- = R_1 = 5\ \text{m}\Omega$
   - Diffusion time constant τ_1 = 240 s,
   - Hysteresis amplitude V_M = 15 mV, hysteresis time constant τ_h = 40 s,
   - Coulomb efficiency η_c = 0.995.

   The system consists of M_p = 7 cells connected in parallel, and N_s = 85 such parallel-connected cell units connected in series.

   Note: between the vbat output of the battery model and the input of the follow-up DC-DC converter include a "Memory" block. This is to avoid an error due to an algebraic loop that would appear between the battery and the DC-DC converter models. The memory block looks like this:

   
   Memory

2. Use idealized functional models for the DC-DC converter, the Motor Drive Inverter, and the Motor, as in the EV models provided in earlier assignments. The vehicle parameters are as follows:
   - DC-DC converter is 100% efficient
   - The reference for the DC-DC converter output voltage is V_{busref} = 500 V
   - Gear ratio (from motor shaft to wheel shaft): g_{ratio} = 7.94
   - Wheel radius r_w = 0.3 m
   - Electric motor is 100% efficient
   - Motor maximum power: 74 kW
   - Motor torque constant is K_e = 0.407 Nm/A
   - Vehicle area A_v = 2.16 m^2
   - Vehicle base speed: v_b = 25 mph
   - Vehicle mass: M_v = 1500 kg
   - Vehicle drag coefficient C_d = 0.26
   - Rolling resistance coefficient C_r = 0.01
   - Vehicle controller is designed so that the cross-over frequency is 2 Hz

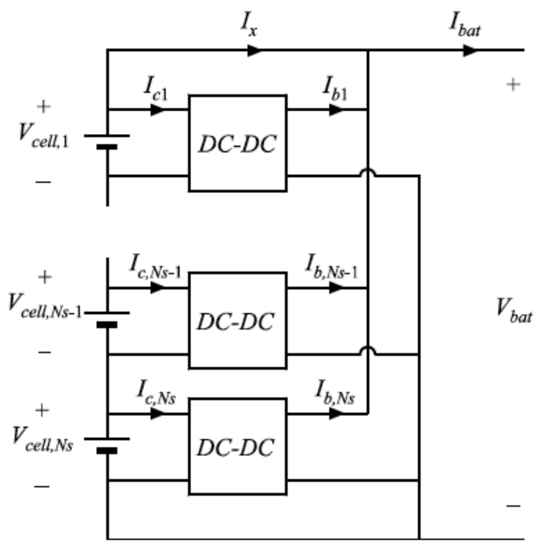
All parameters should be defined in an InitiateModel.m MATLAB script following the practice in the models used in earlier homework assignments.

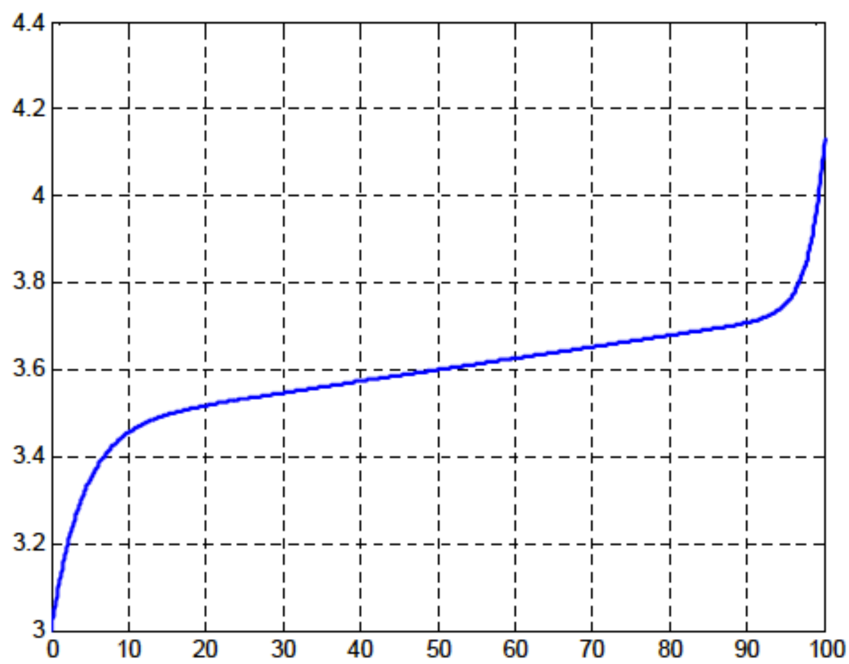
Construct the complete EV model in MATLAB/Simulink. Then, run simulations of the **hwy** drive cycle to determine the minimum initial battery SOC_0 necessary to complete one full drive cycle without allowing the SOC to go below SOC_min = 20%. In your solution report and turn in the following:

(a) Value of SOC_0
(b) Values of the minimum and the maximum battery voltage over the drive cycle
(c) Values of the maximum battery charging current and the maximum battery discharging current over the drive cycle
(d) Plots of the battery SOC, battery voltage, and battery current as functions of time.

Active balancing of battery cells using DC-DC converters

A battery system is constructed as shown below using N_s = 100 cells with nominal capacity C_{nom} = 20 Ah ± 5%. You may assume that the cells in the system have uniformly distributed capacities C_i between C_{min} = 19 Ah and C_{max} = 21 Ah. The open-circuit cell voltage V_{cell} as a function of SOC is shown below, and is defined as a look-up table in **batt_V_SOC.mat**. You may assume that series voltage drops are very small, $R_o = R_o^+ = R_o^- = R_1 \approx 0$ mΩ, hysteresis amplitude $V_M \approx 0$ mV. The DC-DC converters are controlled so that all cells remain balanced at all times, SOC = SOC_1 = … = SOC_{Ns}.





Starting from the fully charge state, SOC = 100%, the battery pack is discharged at a constant 1C rate. The cell-to-pack DC-DC converters can be considered 100% efficient, and are capable of processing power only in the direction from cell to pack, i.e., $I_{ci} \geq 0$.

(a) What is the system capacity C_{system}?
(b) What should the power rating of each DC-DC converter be?
(c) When the system is at SOC = 50%, find the currents I_c, I_b and power processed for a DC-DC converter attached to a cell that has nominal capacity equal to 20 Ah.
(d) When the system is at SOC = 50%, what is the total power processed by the DC-DC converters?