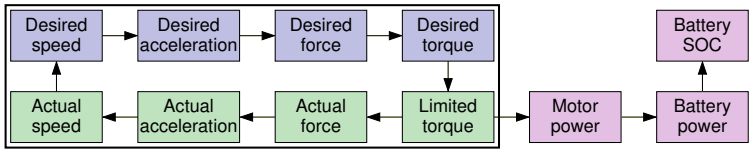
Considering battery limits

- Equations developed so far show whether vehicle is able to develop accelerations required to follow specific drive profile



- They assume sufficient battery power is available to supply motor demand
- To determine range based on battery capacity, battery must also be simulated
  - When a minimum battery SOC or voltage is reached, distance driven to that point is vehicle range

Computing battery power demand

- First, instantaneous power required by the motor is computed

$$\text{motor power [kW]} = \left(\frac{\text{motor speed [RPM]} + \text{previous motor speed [RPM]}}{2}\right) \times 2\pi\ [\text{rev}^{-1}] \times \text{limited torque at motor [N m]}/(60\ [\text{s min}^{-1}] \times 1000\ [\text{W kW}^{-1}])$$

- Depending on whether motor power is positive (accel.) or negative (regen/decel.) battery power [kW] is calculated as

$$\begin{pmatrix}\text{battery}\\ \text{power}\end{pmatrix} = \begin{cases}\text{overhead power} + \text{motor power/drivetrain efficiency [u/l]}, & \text{accel.}\\ \text{overhead power} + \text{motor power} \times \text{drivetrain efficiency [u/l]}, & \text{decel.}\end{cases}$$

where overhead power is constant power drain from other vehicle systems, such as air conditioners, “infotainment” systems etc.

Computing vehicle range

- Assuming battery voltage is constant (a poor assumption)

$$\text{battery current [A]} = \frac{\text{battery power} \times 1000\ [\text{W kW}^{-1}]}{\text{battery nominal voltage [V]}}$$

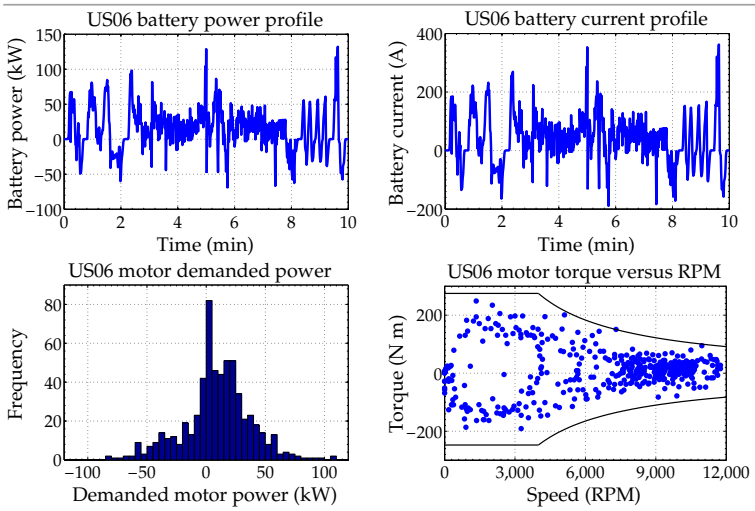
- Battery state of charge is updated as

$$\text{battery SOC}\ [\%] = \text{prior battery SOC}\ [\%] - \text{battery current [A]} \times 1\ [\text{s}]/(3600\ [\text{s hr}^{-1}] \times \text{battery capacity [A hr]}) \times 100\ [\%]$$

- Driving range is extrapolated from the drive cycle calculations

$$\text{range [miles or km]} = \text{total distance of simulated drive cycle [miles or km]} \times \frac{\text{max. rated battery SOC}\ [\%] - \text{min. rated battery SOC}\ [\%]}{\text{SOC at beginning}\ [\%] - \text{SOC at end of drive cycle}\ [\%]}$$

EV simulation results



- Example results using approximate "Gen 1 Chevy Volt" parameters and US06 drive profile
- Results can be used to size motor, battery, electrical systems. . .

Summary

- Have now developed full set of equations for EV simulation
- While model is simple, it provides quite good first-order estimates of vehicle range and other drivetrain load factor
- Example range estimates for approximate "Gen 1 Chevy Volt" parameter values agree reasonably well with actual vehicle
- Still, could improve battery model and perform true co-simulation, could improve motor efficiency map, and perhaps any number of factors

Drive Profile	Range Estimate
NYCC	51.9 km
UDDS	62.8 km
US06	46.7 km
HW-FET	63.5 km