



Need for co-simulation of battery and load

- When designing batteries, important to be able to co-simulate pack and load before proceeding too far down design path
- Ensures pack can meet all performance requirements before large investment made
- One application of interest for large battery packs is for energy storage in xEVs
- To predict battery demand, we must simulate the vehicle over a number of real-world operating scenarios, to determine required battery power or current profiles
 - HEV sims are extremely complex: IC engine, multi-speed transmission, hybrid blending control algorithms need to be simulated accurately
 - EV (and PHEV in electric-only mode) sims fairly straightforward: no IC engine, only a single-speed fixed gearing, no power-source blending

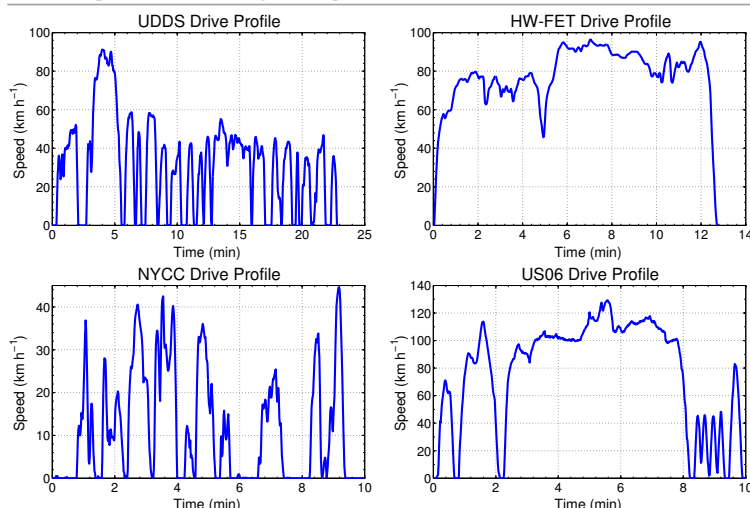


Simulating an electric vehicle

- To simulate electric vehicle, need two things:
 1. An accurate description of vehicle itself
 2. Task the vehicle is required to accomplish
- Vehicle description includes characteristics of battery (cell, module, pack); motor and inverter (motor driving power electronics), drivetrain, etc.
- Vehicle's task is to follow desired profile of speed vs. time ("drive cycle")—e.g.,
 - The Urban Dynamometer Driving Schedule (UDDS)
 - The Highway Fuel Efficiency Test (HW-FET)
 - The New York City Cycle (NYCC)
 - The US06 drive cycle (recorded by NREL, near Golden, CO)



Example drive-cycle profiles

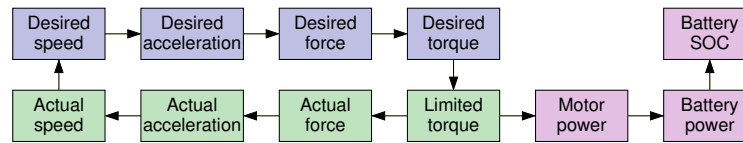


- Four drive cycles are provided to you
- Each has 1 Hz sample rate
- All simulated using same basic equations, developed in next lessons



Approach to simulating an electric vehicle

- Compute (second-by-second) desired accelerations to match desired speed, therefore desired road forces, motor torques



- Desired torque and power values restricted by specifications of motor chosen for vehicle, and thus achievable torques and power values may be lower
- Achievable torques computed, and therefore achieved road force and velocity
- Battery power computed based on motor power, and battery SOC is updated
- Vehicle range extrapolated from rate of battery energy depletion



Summary

- Valuable to be able to co-simulate battery and load
- We look at example of electric-vehicle simulation, which shows some relevant details but is simple enough to develop fairly quickly
- Approach is to determine desired acceleration, road force, torque to meet demanded speed profile
- Then, torque/power/speed limited by motor and drivetrain specs, actual force, acceleration, and speed computed
- Output of interest will be battery demand versus time