ECE 398GG Prof. George Gross
Spring 2023

Homework 3 on

Prof. Krein's Lecture on EV Batteries and Their Management

Date due: Friday, February 17, 2023

In the solution of problems 1 – 4, ignore battery losses with the implication that those losses are included in the grid losses. A more thorough approach is to assume a battery round-trip efficiency in the 85 – 95 *%* range to get a more concrete idea. However, for the purposes of this course, such level of detail is not required.

1. An *EV* has been equipped with a *Li-ion* battery pack with a 100 *%* state of charge (*s.o.c.*) rating of 80 *kWh*. The *EV* requires about 200 *Wh*/*mi* for city driving and 250 *Wh*/*mi* for modest-speed highway cruising. We wish to analyze its functionality with respect to the *US* average round-trip commute distance of 32 miles.

a. For a commute in an urban setting, **determine** the amount of energy that needs to be recovered at work during the day or at night at home. You need to consider all the possible scenarios including the one in which charging is either available or unavailable at one of the two locations.

b. Given a specified *C*/5 recharge rate, **calculate** the charge time needed for a one-way commute and for the full round-trip commute. Comment on the results if the charger is limited to 1.4 *kW* output.

c. In case that the user seeks to refill to at least 80-% *s.o.c.* over a short time after a daily commute, is daily fast charging required? If so, **determine** in terms of the *C* parameter the rate required to recover to the 80-*%* *s.o.c.* in 10 minutes.

2. A large truck is equipped with a 700-*kWh* battery pack and consumes about 2,500 *Wh/mi* for highway cruising. Truck drivers must take breaks of at least 30-*min* duration after driving a maximum of 8 *h*. Moreover, they are allowed to drive only 11 *h* during a 14-*h* total shift. The driver must then be off-duty for the remaining 10 *h* in a 24-*h* day.

a. **Determine** the distance this truck travel between breaks, given that all of the following constraints must not be violated:

- 8 *h* maximum continuous operation
- 70 *mph* maximum speed
- keep *s.o.c.* at or above 20%

Which of these constraints is the most restrictive and is met ahead of either of the other two constraints and becomes binding?

b. **Compute** the charge rate required to recover all of the energy use if charging is possible for all 3 hours of the required breaks?

c. Subject to the constraints in part (a), **determine** the charge rate required to make use of all the downtime and restore full range every 24 hours?

3. *Li-ion* battery range, in effect, the energy capability, at 0 °*C* is about 60 *%* of the value at 25 °*C*. This temperature impacts the effective battery pack capability and also affects the *C* rate: a cold battery needs to be charged more slowly than a warm one. Repeat the problem **1.** above for a low-temperature commute with the same *EV*. However, assume that the cabin heat load requires an additional 50 *Wh*/*mi* for the commute.

4. A hypothetical battery offers double both the energy density and the power density compared to a widely available *Li-ion*-cell-based battery pack. Based on your analysis and results in the solution of the problems above, comment on the impacts of such a technology. Carry out your analysis under the assumption that the costs *per kWh* of the technology is double that of *Li-ion* technology.