Hybrid Storage Model

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October 30, 2017

1 Introduction

This model describes the energy flows in a two- storage system. It will be formulated as a dynamic programming problem.

2 Model

2.1 Definitions

- Indices i: discrete time step index j: storage device number (1: battery, 2: supercapacitor)
- Parameters α^C: charging efficiency α^D: discharging efficiency β: storage efficiency factor (constant) N: number of steps (DP horizon) K: cost weighting factor for rate (relative to cost of energy loss)
- Variables L: load energy demand (Random Variable!!) E: energy state of storage device D: energy released by discharging (AFTER loss) C: energy consumed by charging (BEFORE loss) J: value function

NOTE: C_1 does not exist because not possible to charge the battery while driving. (Assuming no regenerative braking at the moment.)

2.2 Constraints

- Supply demand balance:

$$[D_1(i)] + [D_2(i)] - [C_2(i)] = L(i)$$

- Stored energy changes, including constant leakage loss:

$$E_1(i+1) = \beta_1 E_1(i) + \left[-\frac{1}{\alpha_1^D} D_1(i) \right]$$

$$E_2(i+1) = \beta_2 E_2(i) + \left[\alpha_2^C C_2(i) - \frac{1}{\alpha_2^D} D_2(i) \right]$$

- Bounds on stored energy:

$$E_j^{min} \leq E_j(i) \leq E_j^{max}$$

- Bounds on charging:

$$0 \leq C_2(i) \leq C_2^{max}$$

- Bounds on discharging:

$$0 \leq D_j(i) \leq D_j^{max}$$

2.3 Objective Function

- Minimize charge and discharge rates for the first storage device (battery):

$$J_{rate} = min \left[\sum_{i=0}^{N} K \left[D_1(i) \right]^2 \right]$$

- Minimize power loss due to energy transfers

$$J_{loss} = min \left[\sum_{i=0}^{N} (1 - \alpha_1^D) D_1(i) + (1 - \alpha_2^C) C_2(i) + (1 - \alpha_2^D) D_2(i) + \right]$$

References