A Model Predictive Control-based State of Power Estimation Algorithm Using Adaptive Weighting

Aloisio Kawakita de Souza, Gregory L. Plett, M. Scott Trimboli

University of Colorado Colorado Springs, USA

akawakit@uccs.edu, gplett@uccs.edu, mtrimbol@uccs.edu

1220026

Summary

- Dynamic power management (DPM) is critical for ensuring efficient energy utilization for electric vehicles (EVs) and relies on the ability to supply the battery management system (BMS) with timely and accurate estimates of battery **state of power** (SOP) – i.e., power available over a set time period
- This work presents a robust algorithm for SOP computation using a **model predictive control** (MPC) framework and a coupled electro-thermal equivalent circuit model (ECM)
- The method incorporates a **novel adaptive strategy** for adjusting MPC parameters in order to improve accuracy and increase algorithm robustness

MPC-Based SOP Estimation Method

- MPC-based SOP estimation is based on the computation of fast-charge/discharge optimal profiles by solving a pseudo min time problem:

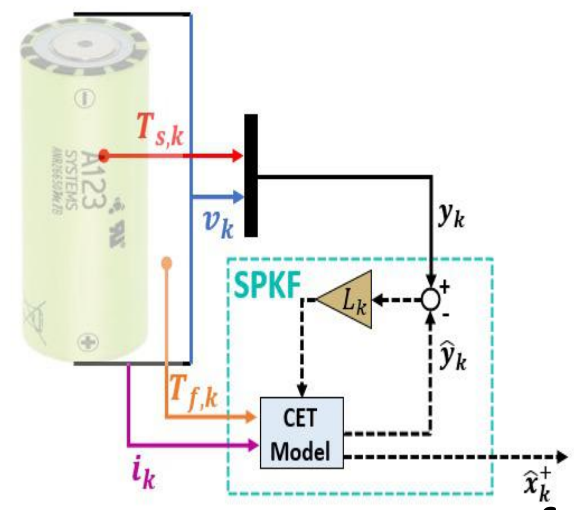
$$J_k = \left\| \underset{\to}{r}_{k+1} - \underset{\to}{y}_{k+1} \right\|_S^2 + \left\| \Delta \underset{\to}{u}_{k+1} \right\|_{\bar{R}}^2$$

(target reference; predicted output; incremental input)

- $\bar{R} = r_w I_{n_c}$ is the input weighting matrix and r_w is the proposed **adaptive input weighting**
- The adaptive weight value is computed based on the norm size of a particular matrix used in the unconstrained quadratic solution

CET Model and State Estimation

- The underlying model is a low-order coupled electro-thermal (CET) equivalent circuit whose architecture was presented in a previous work
- Parameterization is for a 2.5Ah A123 26650 LFP battery cell
- Accurate state estimation using the CET model states is performed via a sigma-point Kalman filter (SPKF) algorithm



- The SPKF observer uses measurements of current, voltage and surface temperature to estimate SOC, hysteresis and core temperature

Simulation Results

- The viability of the proposed approach (SAMPC) is investigated by simulation comparing with standard MPC (SMPC) for SOP predictions computed for four different input control weights: 10^{-6}(SMPC1), 10^{-7}(SPMC2), 10^{-8}(SPMC3) and 10^{-9} (SPMC4)
- Simulation is based on experimental data gathered from dynamic discharge testing, which comprised a high discharge profile for a Formula SAE electric race car completing an endurance test where the cell is discharged from 100% to 2% SOC

SOP constraints	
Charge	Discharge
$z \leq 95\%$	$z \geq 95\%$
$v \leq 3.7$ V	$v \geq 2.4$ V
-25 A $\leq i \leq 0$ A	0 A $\leq i \leq 50$ A
$T \leq 50$ °C	$T \leq 50$ °C

Matlab® code is available for download in the Github repository [20]