Control-Oriented Steady-State Discharge Modelling of Supercapacitors and Batteries for Closed-Loop BLDC Motor Systems Using ARX and ARMAX Model

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Abstract

This paper investigates control-oriented steady-state discharge modelling of a supercapacitor (SC) and a lithium-ion battery supplying a brushless DC (BLDC) motor in a closed-loop system. The study addresses the lack of discharge models that represent energy storage behavior under motor loading conditions, which is critical for accurate current regulation in electric vehicle applications. Linear black-box identification using ARX and ARMAX structures is employed to model the relationship between PWM duty cycle and discharge current at fixed operating points. Experimental data are collected from a laboratory-scale BLDC drive with a sampling time of 0.01 s, focusing on steady-state operation at reference currents of 0.4 A and 0.6 A. System identification is performed using

segmented datasets, and model orders are selected through a guided process that prioritizes low computational complexity while maximizing best-fit accuracy. Model performance is evaluated using prediction best-fit metrics. Results show that ARMAX models consistently outperform ARX models, achieving best-fit values of up to 91.96% for the SC and 89.84% for the battery, representing an improvement of approximately 3%. This improvement indicates enhanced prediction accuracy and disturbance handling, which directly supports smoother and more reliable closed-loop current control. The research contributes a validated modelling framework for EV energy storage systems that enables accurate current estimation and improved control efficiency. © 2025 The Authors.

Author keywords

ARX and ARMAX Model; BLDC Motor; Close-Loop System; Steady-State Discharge; Supercapacitor Battery

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