A Model Predictive Control Application for a Constrained Fast Charge of Lithium-ion Batteries

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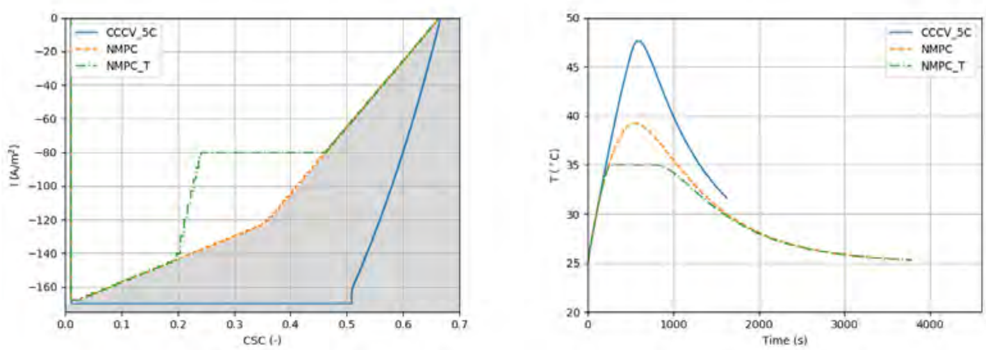
The spread of electrical storage devices continues to be underpinned by the limited charging currents that can be applied. The limitation arises from the lack of sufficient high power charging stations, either at home or along roads and highways, and from the maximum admissible current that can be applied to the battery before undesirable degradation mechanisms are triggered. Accordingly, traditional charging protocols limit the charging current as a function of the standing state of charge of the battery. An example of these is the widespread constant-current-constant-voltage (CCCV) protocol. Protocols like this are designed empirically and restrict the potential benefit in charging time of more flexible charging options. However, the alternative to traditional protocols must rely on a more precise knowledge of the operating constraints and on advanced control techniques to compute online the best operating plan.

This work presents a non-linear model predictive control (NMPC) application to minimize the charging time of a lithium-ion battery subject to electrochemical and thermal constraints. The satisfaction of these constraints (Fig. 1) ensures that the battery degradation is minimized, or at least mitigated. The programming language Modelica and the optimization and simulation framework JModelica.org is used in combination with Python language to assess the implementation time and potential use of NMPC in commercial batteries to extend their operational life.



(a)   (b)

Figure 1. Comparison of a traditional charge protocol (CCCV) with non-linear constrained control without (NMPC) and with (NMPC_T) temperature constraint ($T_{\max} = 35°C$). Left: Current (I) and Critical Surface Concentration (CSC) phase plot (in grey the unfeasible region); right: temperature profiles