A Model-Predictive-Control-Based Power Management Strategy for a Power-split Hybrid Electric Vehicle

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Abstract: Nowadays, due to the shortage of oil resources and the significant problems of environment, people are engaged in pursuing electric vehicles. But because of the restrictions of battery technology, pure electric vehicles are unable to meet people's daily needs. Hybrid electric vehicles (HEV) are seen as a viable solution to this problem in the nearby future. Basically, HEVs are divided into three structural types, series, parallel and power-split. The main drawback of a series HEV is low efficiency due to so much energy conversion. And the main drawback of a parallel HEV is poor fuel economy due to interdependence of engine speed and vehicle speed. Despite its complex structure and difficult control, a power-split HEV may combine these advantages and make up for the disadvantages.

In a power-split hybrid electric vehicle, with the help of two electric motors, the engine's working point is decoupled from the vehicle's operating point within certain limits. Then the engine's working point can be adjusted to more efficient areas. So the improvement of fuel economy is strongly dependent on the power management strategy. Many studies have already been made. In industry, most approaches use rule-based control which is easy to achieve. But such methods are not optimized. Some optimization-based control methods have been studied, such as DP (Dynamic Programming) and ECMS (Equivalent Consumption Minimizations Strategy). However, methods like pure DP are non-causal and require too much computation for real time implementation. Methods like ECMS get an optimal solution in a certain point in time, but it is not optimal over an extended time period.

In this paper, a real-time optimal control method based on nonlinear model predictive control (NMPC) is studied. Dynamic programming is used on a simplified model, and the finite time horizon of NMPC offers the potential for real time implementation. This produces the power management strategy. The MMPC approach solves an optimization problem over a predictive future horizon that minimizes fuel consumption while maintaining the battery's state of charge. The resulting NMPC control law is then evaluated in simulations employing a more complex closed-loop model. Results over different driving cycles show that this NMPC-based power management strategy gets a noticeable improvement in fuel economy.

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