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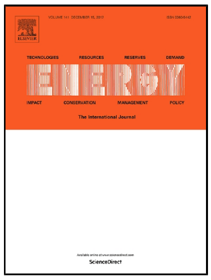

A systematic design and optimization method of transmission system and power management for a plug-in hybrid electric vehicle

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A systematic design and optimization method of transmission system and power management for a plug-in hybrid electric vehicle

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Abstract: The transmission system together with power management will simultaneously affect the fuel economy of the plug-in hybrid electric vehicle (PHEV) with automated mechanical transmission (AMT). This paper strives to make three contributions to realize systematic design and optimization of the transmission and power management. Firstly, a design of experiment method is proposed to redesign the current transmission system of the PHEV with Optimal Latin Hypercube Design algorithm. Then, a co-optimization method is proposed to insight into the preferable speed ratios of the redesigned transmission system with multi-island genetic and dynamic programming algorithms. Finally, a Pontryagin's Minimum Principle-based self-identification controller is proposed to realize adaptive power management control, based on a significant finding that the constant solution of the co-state from off-line iteration optimization can be approximately identified by the mean value of the co-state with time-moving in the self-identification controller. Results demonstrate that the current 6-speed ratio AMT can be reduced to 4, the fuel economy of the redesigned transmission system can be improved by 2.9% compared to the current transmission system and the self-identification controller can further improve the fuel economy of the PHEV compared to the conventional PI controller.

Keywords: Plug-in hybrid electric vehicle; Transmission system; Design of experiment; Co-optimization; Power management

1. Introduction

Plug-in hybrid electric vehicles (PHEVs) have been gained a great deal of concern in the past decades [1]. The excellent fuel economy of PHEVs is greatly benefited from well-designed components and power management. The well-design of PHEVs can be formulated as a complicated multi-objective and multi-constraint optimization problem with strong coupling relationship between components and power management [2].

A systematic design and optimization method of components and power management is of great importance to realize the system optimality of PHEVs. It can be divided into two categories: the optimal matching among powertrain topology, component size and power management; the integrated optimization between component size and power management based on a given powertrain topology. The former can realize systematic optimality, but only the configuration of power-split is usually investigated [3-5]. The latter has no configuration restriction, but the optimality is usually restricted to a given powertrain topology [6-9]. For the optimization methods, convex optimization integrated with dynamic programming (DP) is one of the most notable and applicable methods for the systematic design of PHEVs [10-14]. In addition, genetic algorithm, parallel chaos optimization algorithm and non-dominated sorting genetic algorithm-II (NSGA-II) et al. are also extensively investigated by many researchers [2, 15-16].

The configuration of the single-shaft parallel PHEV with automated mechanical transmission (AMT) has been gained comprehensive attention by many auto-makers, owing to its characteristic of the compact layout and multi-working mode [17, 18]. Since the fuel economy of the single-parallel PHEV can be simultaneously influenced by transmission system and power management, a systematic design and optimization method of the transmission system and power