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Shared Control Based Energy Management Strategy for Hybrid Electric Vehicle Taking into Account Demand Power Optimization

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Abstract

To further explore the potential of fuel economy for hybrid electric vehicle (HEV), a shared-control-based energy management strategy (SCEMS) with four modules of the human-vehicle closed-loop system, reference power calculation, driver power distribution, and shared control strategy is proposed. The SCEMS possesses three innovations. Firstly, the rational driver's power demand is considered to achieve optimal fuel consumption. Secondly, a dimensionality reduction strategy of two-dimension DP algorithm is proposed for online application. Finally, based on the shared control and the intelligent traffic system (ITS) a game mechanism between driver and controller is constructed to adapt to different driving styles and road conditions. In the human-vehicle closed-loop system, a model is built, combining the driver model with a longitudinal dynamic model, to optimize the power demand and power distribution. In the reference power calculation, the dynamic programming (DP) algorithm is utilized to produce the optimal power of a future forward road segment based on the ITS. The time complexity of DP algorithm is reduced by a state of charge (SOC) table looked up online derived from neural network and road condition identification. In the driver power distribution, the original demand power is assigned to the engine and motor. In the shared control strategy, two condition description equations are respectively constructed to indicate the fuel consumption rate of the engine and the efficiency of the motor, and then two adjustment curves are fitted to regulate the proportion of driver and controller to improve the power-wasting and ineffective behaviors. The problem of driving style and emergency road condition adaptation is settled depending on the cumulative-error-based weight adjustment strategy.

Introduction

Plug-in Hybrid Electric Vehicle (PHEV) can obtain electric energy from the external power grid through charging, and its strategy is to consume electricity to the lower limit within the determined range of travel, reduce part of the fuel consumption, and adjust the engine to work in the high-efficiency area. The EMS of PHEV is mainly divided into optimization-based strategy and rule-based strategy. With the development of new technologies such as the internet of vehicles, some new strategies have also emerged. Optimization-based EMS refers to strategies that use optimization algorithms to solve solutions, mainly including DP, PMP, and GT. C. Romaus et al. [1] have presented a strategy to control power distribution with DP based on consideration of traffic conditions and random effects of drivers. The rule-based energy management strategy has become the first choice for practical engineering applications due to its simple structure, small computational complexity, and low memory footprint, mainly including CDCD and NN. To overcome the shortcomings of NN, literature [2] has proposed a control rule to extract the optimal solution of multiple typical working conditions and a strategy of selecting corresponding rules based on working condition identification in the online application. With the rapid development of ITS centered on intelligent network technology, the traditional EMS has gained new vitality. Reference [3] has proposed a PHEV energy management system based on vehicle-vehicle, vehicle-road communication system, and cloud computing for vehicle speed prediction. For different application scenarios such as intersections, the author uses the obtained surrounding vehicle and traffic light information, combined with the car following model to predict the future speed of the vehicle. The prediction algorithm adopts an improved chain NN taking the prediction result of the previous step as one of the inputs of the next prediction, which is similar to the idea of a recursive network, and the prediction accuracy is greatly improved. Finally, according to the guidance of future road condition information, the equivalent factor of the ECMS strategy is adjusted in real-time. Compared with the traditional adaptive ECMS, the economy of this strategy is improved by about 5%. Ozatay E et al. [4] have proposed a cloud computing-based optimal vehicle speed assistance decision system for HEV. The

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Definitions/Abbreviations

PHEV - plug-in hybrid electric vehicle
SCEMS - shared-control-based energy management strategy
EMS - energy management strategy
ITS - intelligent traffic system
DP - dynamic programming
NN - neural network
SOC - state of charge
PMP - pontryagin's minimum principle
GT - game theory
CDCS - Charge-Depleting Charge-Sustaining

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