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Research on Energy Management Strategy of Hybrid Electric Vehicles Based on Hierarchical Control in the Connected Environment

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1. Introduction

The growing environmental pollution and energy crisis have restricted the development of conventional Internal Combustion Vehicles. To meet these challenges, new energy vehicles have become the focus of research around the world due to their advantages of low energy consumption and low pollution. Although pure electric vehicles have the characteristics of no pollution and zero fuel consumption, due to the limitations of current technology, such as small power battery capacity, short life, short driving range, etc., severely restrict the further development of pure electric vehicles. Therefore, hybrid vehicles that combine the advantages of pure electric vehicles and conventional vehicles have become the development trend of automobiles at this stage.

Energy management is the core technology of hybrid electric vehicles, and plays a vital role in fuel economy and emission performance of automobiles. Vehicle energy management is related to many factors, such as vehicle velocity, road slope, and traffic information. Most of the current vehicle’s energy management is based on known operating conditions, without considering actual road traffic information, which prevents the vehicle from achieving optimal energy control. In recent years, with the development of Intelligent Transportation System (ITS) and Global Positioning System (GPS), vehicles can communicate with vehicles (V2V), and can communicate with transportation facilities (V2I) . All this information can help optimize vehicle energy management, thereby improving fuel economy performance.

In view of the above problems, the hierarchical energy management structure to improve the vehicle energy optimization is studied in this paper. The hierarchical management structure is composed of two controllers, where the upper controller predicts the vehicle optimal target velocity using model predictive control algorithm with the traffic information, the lower controller uses the control algorithm based on the fuzzy neural network to allocate the required power of the vehicle between the engine and the motor according to the predicted velocity obtained by the upper controller, so as to achieve the purpose of improving fuel economy.

2. Modeling

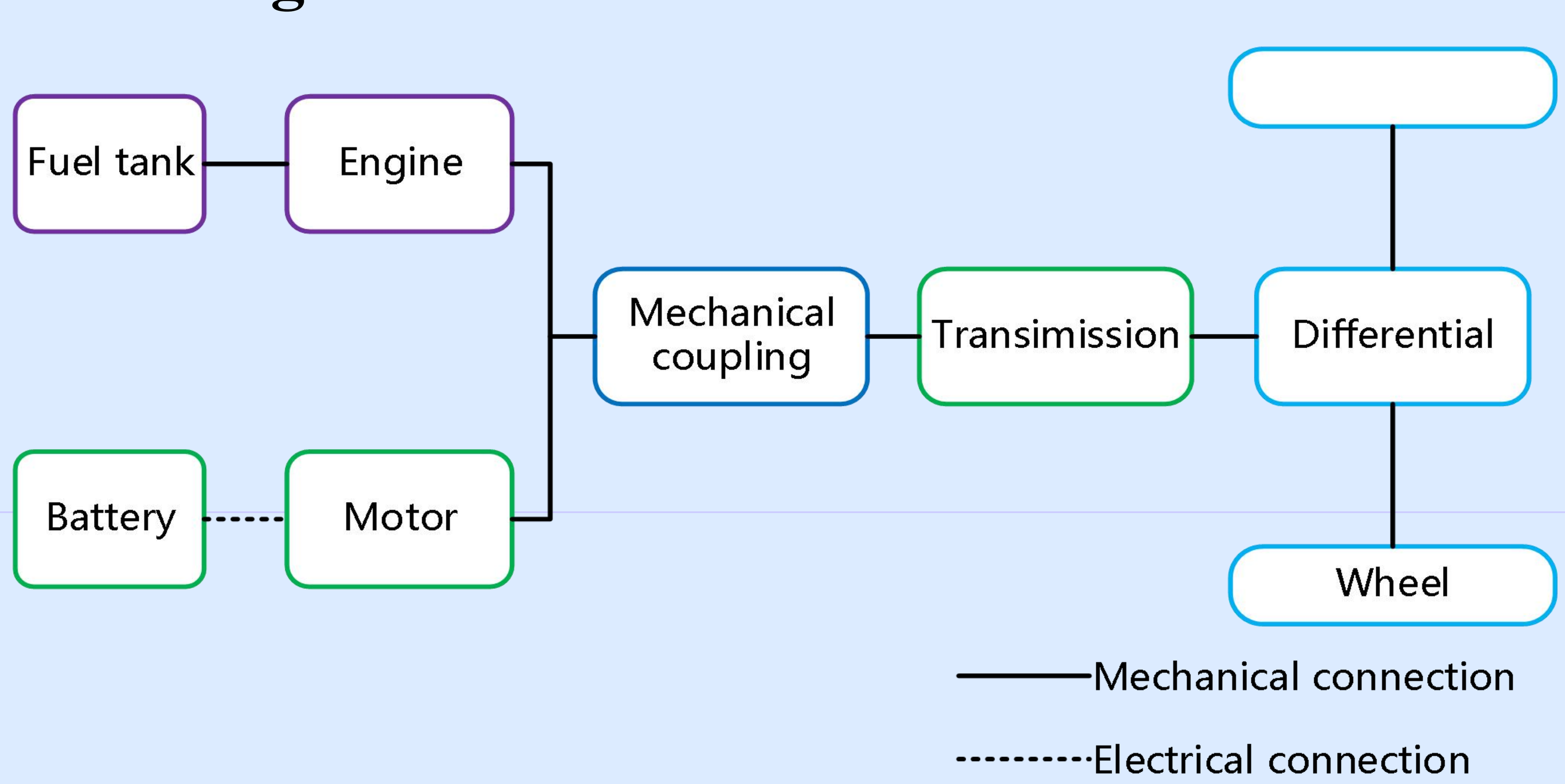

Fig 1. Structure of Parallel HEV.

3. The Controller Design

3.1 Optimization Method Design

The designed vehicle energy management method is a hierarchical controller, whose specific structure is shown in Figure 2. The upper controller uses the model predictive control algorithm and combines road traffic information to solve the vehicle's optimal target velocity. The lower controller uses the fuzzy neural network algorithm to reasonably distribute the vehicle's required power between the engine and the motor.

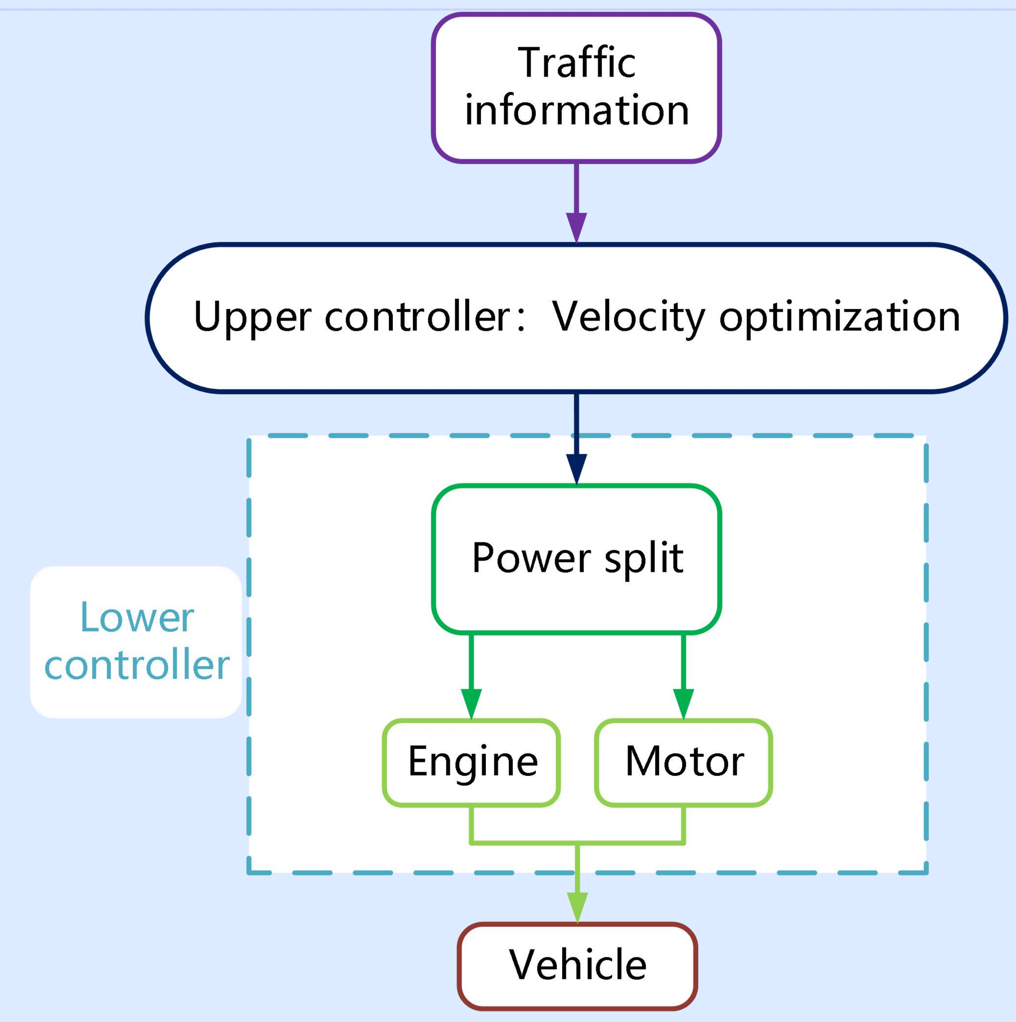

Fig2. Hierarchical Energy Management Structure

3.2 Velocity Optimization for Eco-driving

First, according to the road traffic information, the vehicle can smoothly pass the traffic signal without stopping to reduce the parking time. From this, the target velocity range of the vehicle can be calculated.Then，when using model predictive control to study the optimal vehicle velocity, it is necessary to comprehensively optimize the vehicle's fuel economy, traffic congestion, and acceleration and deceleration times.

3.3 Power Split Under the Optimal Velocity

After the upper controller obtains the optimal vehicle target velocity, the lower controller, fuzzy neural network controller, mainly performs the optimal allocation of the required power of the vehicle between the engine and the motor based on the predicted velocity obtained by the upper controller.

4. Simulation Results and Analysis

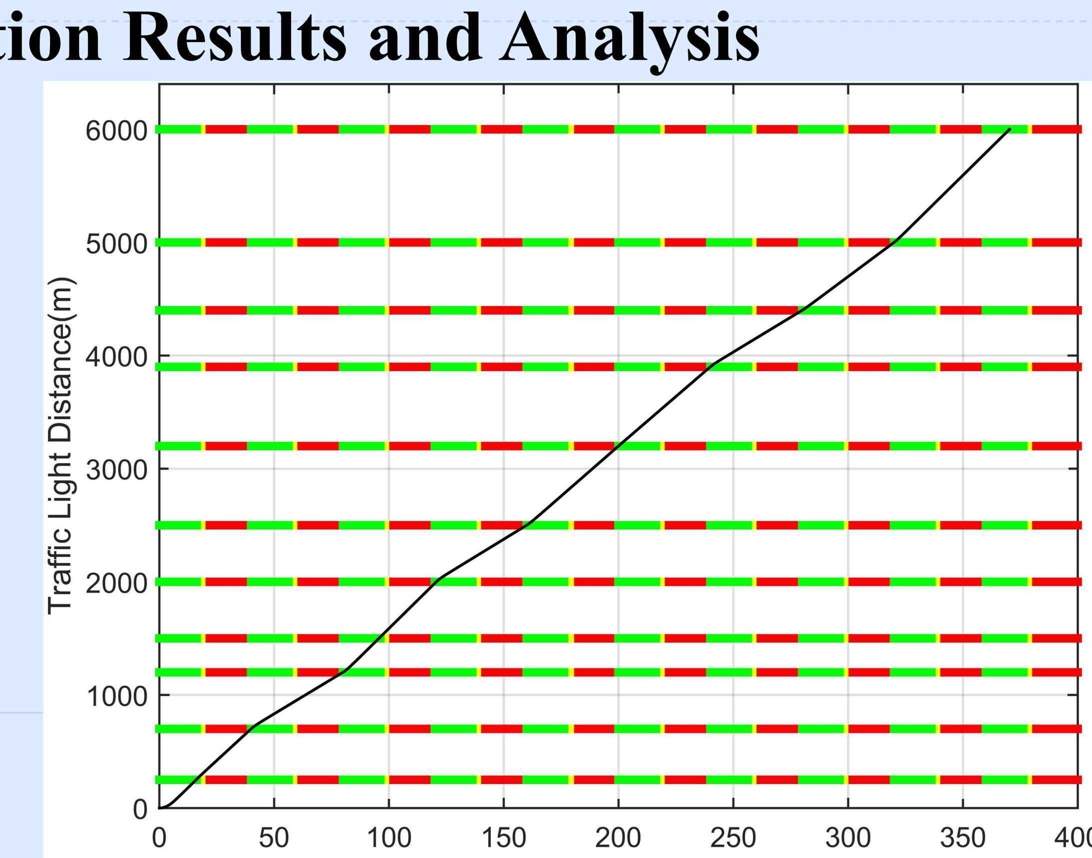

Fig 3. vehicle velocity optimization on the upper controller.

Table 1. Comparison of simulation results between CS-CD and FNN

	CS-CD	FNN
FC(L/100km)	4.3	2.8
HC(g/km)	0.557	0.498
CO(g/km)	7.879	2.664
NOx(g/km)	0.286	0.283

The simulation results show that Figure 3 is the vehicle velocity optimization achieved by the upper controller. Table 1 is the energy consumption and emission results of energy management using logical threshold (CS-CD) and fuzzy neural network (FNN), respectively.The simulation results indicate that the fuzzy neural network controller can be applied to the energy management strategy of HEVs, which can reasonably distribute the vehicle's required power between the engine and the motor.

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