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Energy management strategy of a plug-in parallel hybrid electric vehicle using fuzzy control

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Abstract

Plug-in hybrid electric vehicle is an important measure to achieve energy saving and emission reduction. Energy management strategy is one of the most important parts in the research of PHEV, which has important influence on the performance of the whole vehicle. In this paper, a plug-in parallel hybrid electric vehicle is employed as the research object: firstly, a rule-based algorithm is established; then, an energy management strategy using fuzzy control is presented to improve the rule-based algorithm; finally, the proposed control strategies are simulated and verified under three typical driving cycles. The result shows that the proposed fuzzy control strategy can achieve a more smooth control effect to alleviate the decline rate of the battery State of Charge (SoC) and significant fuel consumption reduction could be achieved compared with the rule-based algorithm. Under certain driving conditions, fuzzy control strategy can achieve an extension of Charge Depleting (CD) phase by up to 4.45% and the reduction in energy loss can be up to 5.99%.

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*Keywords:*hybrid electric vehicle;rule-based;fuzzy control;energy management;

1. Introduction

Environmental pollution and energy shortage have always been the two big problems which restrict the development of automotive industry. Plug-in hybrid electric vehicle (PHEV) is a new type of hybrid electric vehicles between fuel vehicles and electric vehicles, which can not only keep a certain distance of pure electric drive, but hybrid drive to improve fuel economy [1]. As a viable solution of the environment pollution and energy crisis, it has attracted a lot of attentions from organizations and companies. Control strategy is one of the most important parts in the research of PHEV, effecting the fuel economy and

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exhaust emissions. Therefore, it has important theoretical significance and practical value to build up an effective control strategy [2].

There are three major categories of energy management strategy. (i) A rule-based algorithm [3, 4]: the basic idea of this method is to limit the working range of the parameters through setting threshold parameters, and adjust the components working status according to the vehicle real-time parameters and the pre-set rules, and then the vehicle energy loss can be reduced. This method has many advantages, such as simple structure, small amount of computation and high execution efficiency, and it is more suitable for the real-time energy management. However, the settings of threshold parameters usually rely on experience, so it cannot guarantee the optimization of the vehicle fuel economy. (ii) Intelligent control method: intelligent control can solve many complex uncertain system control problems by integrating human knowledge into control system, such as fuzzy control [5] and neural network control [6].This kind of method does not need an accurate mathematics model of the controlled system and it also has the advantages of self-learning, self-adaptability, and robustness which can solve some complicated nonlinear problems.(iii) Optimization algorithm: It is based on the optimization theory to set up the optimized math models by restriction of emissions、fuel economy or system state variable. At present, there are particle swarm optimization [7], genetic algorithm [8] and dynamic programming algorithm [9]. These approaches are useful for finding the optimal policy. However, in view of the heavier calculation burden and worse real-time of the algorithm, these methodologies are mainly suitable to analysis and evaluate the effect of other energy management strategies.

The above control methods and algorithms have their own advantages and problems. Considering the rule-based and fuzzy control approaches can be easily implemented in the real-time control due to their simple structure and strong robustness, etc., these two methods are investigated in this paper. The main purpose of this study is to compare the rule-based with fuzzy control method in using the same energy management strategy for PHEV. The remainder of this paper is structured as follows: Section 2 describes the configuration of the PHEV; a rule-based strategy is established at first and then the fuzzy control strategy of the power management for a PHEV is researched in Section 3; the comparison between the proposed fuzzy control strategy and the former rule-based strategy is given in section 4 while the conclusions are summarized in section 5.

2. PHEV configuration

The PHEV with a parallel topology is investigated in this paper, as shown in Figure 1. The torque of engine reaches the front driving axle through the clutch, transmission and final reduction. The torque of motor reaches the rear driving axle through the other final reduction. Charged from power grid, the battery provides energy to the motor, but also retrieves the braking power from generator. The torques from front axle and rear axle are coupled at the ground, achieving a four-wheel driving advantage. The basic parameters of the vehicle are shown in table 1.