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Emissions and fuel economy trade-off for hybrid vehicles using fuzzy logic

Naim A. Kheir [a,*], Mutasim A. Salman [b], Niels J. Schouten [a]

[a] *Electrical and Systems Engineering Department, School of Engineering and Computer Sciences, Oakland University, 102A SEB, Rochester, MI 48309, USA*
[b] *General Motors Research and Development Center, 30500 Mound Road, Warren, MI 48090, USA*

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Abstract

In this paper, a generalized fuzzy logic controller (FLC) is used to optimize the fuel economy and reduce the emissions of hybrid vehicles with parallel configuration. Using the driver input, the state of charge (SOC) of the energy storage, the motor/generator speed, the current gear ratio and vehicle speed, a set of 44 rules have been developed, in a fuzzy controller, to effectively determine the power split between the electric machine and the internal combustion engine (ICE). The underlying theme of the fuzzy controller is to optimize the fuel flow and reduce NO_x emission. The parameters in the fuzzy rules can be adjusted to trade-off the fuel economy and the NO_x emission of the vehicle.

Simulation results are used to assess the performance of the controller. A forward-looking hybrid vehicle simulation model is used to implement the control strategies. By using fuzzy logic, trade-off between fuel economy and emission improvement has been shown.

Keywords: Hybrid vehicles; Energy management systems; Fuzzy control; Optimal power flow; Automotive control

1. Introduction

A hybrid system, using a combination of an internal combustion engine (ICE) and electric motor(s), is an important concept to improve fuel economy and reduce emission of vehicles. In the last two decades, the automotive industry has been actively working on several hybrid configurations. This activity has resulted in actual production or plans for near-term production of hybrid vehicles by the major automotive companies [1].

To improve the fuel economy and reduce the emissions of hybrid vehicles, it is important to optimize not only the architecture and components of the hybrid vehicles, but also the energy management strategy.

* Corresponding author. Tel.: +1-248-370-2177; fax: +1-248-370-4633.
E-mail address: kheir@oakland.edu (N.A. Kheir).

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The energy management strategy controls the energy flow among all components as well as the power generation and conversion in the individual components.

There are several approaches for the development of energy management strategies [2–7]. One approach optimizes the engine operation, thus not using the full potential of hybrid technology. A second approach optimizes the instantaneous operation of the hybrid system. This can be done by the minimization of the current equivalent fuel flow and/or the instantaneous emission. In the third approach, global optimization is used where the total fuel consumption and/or emission of the vehicle in a specific driving cycle are minimized.

For the implementation of the energy management strategy, fuzzy logic controller (FLC) is used in this paper. The fuzzy logic controller will be used to implement the energy management strategy that optimizes the operation of the overall hybrid system, based on instantaneous vehicle information. The fuzzy logic controller will be used for both fuel economy optimization and emission reduction by having different parameters tuning. Previous research work [2,3] has indicated that fuzzy logic control is suitable for hybrid vehicle control. It is a suitable method for non-linear systems, with time-varying components. It is flexible, since any energy management strategy approach can be implemented using fuzzy logic. It is also tolerant to imprecise measurements and to component variability. The results of the fuzzy logic are essentially multi-dimensional look-up table-based control.

In Section 2 of this paper, the parallel hybrid vehicle under consideration will be described. Section 3 discusses the energy management strategy concept used by the fuzzy logic. Section 4, an enhanced fuzzy control relative to the one given in [2,3], is presented and the controller is tuned for either fuel economy optimization or emission reduction. Simulation results for the fuzzy logic controller tuned for optimized fuel economy and the one tuned for NO_x emission are shown in Section 5.

2. Parallel hybrid vehicle configuration

Fig. 1 shows the parallel hybrid vehicle configuration that will be used for control design and analysis. This is different from the configuration considered in [2] (as shown in Fig. 2). The electric machine is connected upstream and a continuously variable transmission (CVT) is used instead of an automated manual one (considered in [2]).

The following components have been used for the new configuration:

- Compression ignition direct injection (CIDI) engine: 55 kW.
- Permanent magnet (PM) motor: 20 kW continuous, 40 kW peak, upstream of the transmission.
- Lithium ion (Li-ion) battery: 40 kW, 2 kWh.
- Continuously variable transmission, ratio ranging from 0.5 to 2.5.
- Total test vehicle mass: 1100 kg.

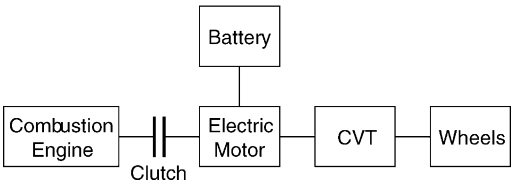

Fig. 1. Block diagram of new PHV configuration.