Abstract

The increasingly stringent emission regulations have been one of the driving forces behind exploring more sustainable vehicle powertrains. On the one hand, carmakers are finding alternatives to meet these regulations; on the other hand, they are trying to improve smart features such as chassis dynamics, passenger comfort, and ride safety. The P0 architecture in a hybrid electric vehicle (HEV) is a cost-effective layout due to its easy adaptation to the existing conventional vehicle architecture. P0 is the layout where the alternator is replaced by the electric machine (EM) on the front-end accessory drive and is coupled to the internal combustion engine (ICE) using the belt drive system (BDS).

The first part of the dissertation seeks to develop energy management solutions for P0 parallel HEVs with the objective of reducing fuel consumption and maximizing system efficiency. In a P0 architecture, fuel consumption and emissions are increased when idling the engine during stops to fulfill cabin air conditioning. Thus, optimal energy management during these events would lead to an improvement in vehicle fuel economy. A FEAD layout is proposed for a HEV by installing an electromagnetic clutch between the ICE and the BDS. It is demonstrated that the proposed solution saves up to 3.4% of fuel as it shuts down the engine and decouples the ICE's resisting torque during stops. Additionally, the transmission losses of the BDS reduce the fuel savings in P0 HEV. Standard energy management systems (EMS) do not account for BDS losses, which are significant in this architecture. In order to maximize the effectiveness of the P0 system, this work provides a novel formulation of the ECMS that considers the power loss map of the BDS in addition to the characteristics of EM and ICE. A test bench is built up to characterize the BDS, and it is verified using an open-loop hardware-in-the-loop (HIL). To find the most appropriate equivalence factors for the equivalent consumption minimization strategy (ECMS), which would ordinarily be tuned through a trial-and-error approach, a genetic algorithm (GA) is used. Two belts in the BDS are tested in simulation to achieve savings of around 0.9

g/km of CO_2 when compared to standard ECMS, demonstrating the efficacy of the proposed controller.

The second half of the dissertation focuses on creating solutions for cooperative intelligent transportation systems (ITS) using machine learning. A solution that can enhance traffic flow, vehicle stability, passenger comfort, and fuel economy is required due to an increase in the number of cars on the road combined with stricter emissions regulations. Adaptive cruise control (ACC) has the potential to meet these requirements, and its performance can be improved through wireless communications. A simulation framework is needed that must assess different aspects, from traffic efficiency to safety and passenger comfort, by including detailed vehicle dynamics and communication models to ensure realistic simulations. A novel simulation framework for the assessment of ITS is presented, accounting for all the most relevant multidisciplinary aspects, namely, wireless connectivity, vehicle interactions along roads, vehicle dynamics and control, and sensors. For a HEV, a multi-objective cooperative adaptive cruise control (CACC) based on deep reinforcement learning (DRL) is proposed. Specifically, as the CACC control actions and EMS power-splitting decisions are interdependent, leading to a design of a multi-agent DRL (MADRL-CACC) solution for the CACC and EMS. The framework has two layers: the upper layer has a DRL agent, which produces throttle or brake pedal commands considering headway, vehicle stability, passenger comfort, and fuel economy; the lower layer uses another DRL agent that computes the equivalence factor of the ECMS. The proposed controller is compared to a proportional feedback controller tuned by a single- and multi-objective genetic algorithm for ACC and a single agent DRL for ACC and CACC applications. All these controllers use ECMS for energy management. In simulations, the performance of the controllers is evaluated in both urban driving and highway driving. The proposed controller finds a better tradeoff between the objectives, which highlights the benefits of wireless communication and the use of an additional DRL agent for EMS. Specifically, in urban driving scenarios, the MADRL-CACC improves fuel economy by 7.9% when compared to a classical ACC tuned with a single-objective genetic algorithm. Additionally, HIL simulations using the dSPACE SCALEXIO AutoBox confirm that trained DRL models can be deployed on real-time hardware platforms.