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Comparative Analysis on Fuel Consumption Between Two Online Strategies for P2 Hybrid Electric Vehicles: Adaptive-RuleBased (A-RB) vs Adaptive-Equivalent Consumption Minimization Strategy (A-ECMS)

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Abstract

Hybrid electric vehicles (HEVs) represent one of the main technological options for reducing vehicle CO_2 emissions, helping car manufacturers (OEMs) to meet the stricter targets which are set by the European Green Deal for new passenger cars at 80 g CO_2/km by 2025. The optimal power-split between the internal combustion engine (ICE) and the electric motor is a challenge since it depends on many unpredictable variables. In fact, HEV improvements in fuel economy and emissions strongly depend on the energy management strategy (EMS) on-board of the vehicle. Dynamic Programming approach (DP), direct methods and Pontryagin's minimum principle (PMP) are some of the most used methodologies to optimize the HEV power-split. In this paper two online strategies are evaluated: an Adaptive-RuleBased (A-RB) and an Adaptive-Equivalent Consumption Minimization Strategy (A-ECMS). At first, a description of the P2 HEV model is made. Second, the two sub-optimal strategies are described in detail and then implemented on the HEV model to derive the fuel-optimal control strategy managing the power split between the thermal and electric engine to satisfy the driver's power request, including the engine on/off operating mode and the best gear selection. Finally, the two proposed strategies are tested on different driving cycles and then compared to other commercial strategies available in literature, such as the Equivalent Consumption Minimization Strategy (ECMS) and a RuleBased (RB) strategy. The results show that the A-ECMS is more conservative in terms of state of charge (SoC) compared to the A-RB. In fact, in the A-ECMS the SoC is always within the admissible range with considerable margin from the upper and lower limits for tested cycles, while in the A-RB a deep discharge of the battery is allowed. This behavior leads to a better fuel consumption of the A-RB compared to the A-ECMS, both in the WLTC and in the FTP-75 cycle.

Introduction

The energy consumption and CO_2 emissions of transport sector, which mainly consist in road, ships, railway and aviation, is very significant due to economic and population growth [1, 2]. Road transportation consumes 75% of the total energy spent on transportation [3]. Since internal combustion engine (ICE) are used in the majority of vehicles, the transportation industry is accountable for 25%-30% of the total greenhouse gases emission [4] Thus, legislations around the world are tending towards low tailpipe emission limits. Important data to be shown are the average CO_2 emissions from new passenger cars: the new passenger car fleet met the 2015 emission target of 130 g CO_2/km two years early, but additional efforts are still required to meet the actual target developments, trying to obtain a control strategy capable of respecting the charge-sustaining constraint by minimizing specific fuel consumption and being valid over several driving cycles.

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