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Optimal Control Strategy Using Cloud for a Parallel Topology Based HEV to Minimize Energy Consumption

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Abstract

Two-wheelers especially scooters constitute a majority market share in Asian countries. A hybrid drive-train integration of electric motor/motors with a conventional IC engine is a suitable solution to achieve reduction in CO_2 emissions and as an alternative to IC Engine only vehicles. A model based supervisory controller is proposed, considering the behavior of the electrical drive, IC engine as well as the transmission, which determines the modes of operation. The controller determines the commanded torque split between the engine and electric motor across all modes of operations. With the information about the driving cycle, an optimal controller based on dynamic programming that minimizes fuel and equivalent electrical energy consumption with charge sustaining feature is proposed. This supervisory controller was simulated for hybrid configuration running on WMTC driving cycle to minimize equivalent energy consumption. The performance of the proposed controller with hybrid powertrain is compared against a conventional powertrain. Cloud Computing is gaining force as it acts as an online fast computing platform enabling scalability, online resource management, seamless integration with hardware along with the most important benefit of reduced computation requirements at the edge. This supervisory controller was hence also implemented on a Cloud Service platform.

Introduction

Hybrid electric powertrains combine the electric drive with the already in place Internal Combustion Engine (ICE). These are configured such that the engine operates in the most efficient region while power demands in the non-efficient regions are met by the electric drive which, thereby, reduces the fuel consumption and emissions. Electric drives are made up of electric machines, motor controller and a battery. They have the capability to provide maximum torque even at low speeds as against an ICE and can regenerate energy due to braking action, which adds to the efficiency of the whole system. Usage of fuel to charge the batteries is also possible to meet battery state of charge requirements. Mild hybrids, particularly, are not designed to have an external charging outlet for the battery. Hence, strategy for recuperation of energy becomes essential for sustaining the battery charge for longer operations.

In case of two-wheelers, scooters have a very compact design and are made to enhance urban drivability. However, the current Continuous Variable Transmission (CVT) exhibits lower fuel economy compared to the ICE based powertrain which is coupled with geared manual transmission. Authors of [1] used a low power 50 cc replacing the CVT. This resulted in a series HEV giving a lesser overall efficiency of just 52%. Recuperation in the motor resulted in 15% energy savings. The authors of [2] developed a characterisation matrix which compares a gearless (CVT) against a geared transmission (MT). The comparison yielded that though CVT gives 25% more fuel consumption, NOx emissions are significantly lesser at 30% of MT. A better ICE operating region was obtained in the Indian Driving Cycle (IDC) test cycle for CVT as the gearless system enabled the engine to operate at lower speed operating regions which delivers better performance in Indian driving conditions. The comparison matrix paves way for the hybrid model to use CVT transmission for drivability reasons.

When the driver demands torque from the drivetrain, the demanded torque has to be split between the engine and the motor so as to have the most efficient operation. Hence, HEVs need a supervisory controller which splits the torque such that there is least energy consumption and exhaust emission. The split torques namely engine torque and motor torque are then sent to respective controllers to achieve the demand. Hence, the need is to develop such a controller under constraints which are in the form of boundary of battery state of charge state, and boundary of engine operating regions and electric machine operating regions. Energy consumption is termed as the cost of operation of the ICE and/or the electric motor for any given torque and speed requirement. The cost to be converted into a mild hybrid powertrain with charge sustaining feature is explored and validated. Under the research, the best fuel economy percentage increase of 43.9% was achieved under the limits of the experimentation and the dependency of the fuel economy on EF was analyzed. The dynamic programming based supervisory controller offered a global minima of energy consumption which sets a benchmark for further development process. More components and variables can be introduced in the powertrain design to account for inverter efficiency, electrical energy usage via the onboard low voltage electronics, effects of system thermodynamics, and variable mass due to long term operation. This will prompt the fuel economy to get closer to real time situations. The research lays down basis for further development of the HEV topology for scooters. The results can be integrated with a characterization matrix of the HEV powertrain as developed under [2] with modifications to compare drivability and ICE efficiency with different EF values. The supervisory controller developed, evidently, depends on the future driving speed trajectories for real time implementation. These trajectory calculations are not considered on this work.

The containerized application architecture provides an option of running a real time controller off-board at a remote location, thus reducing packaging and hardware management and improving software sustainability. The implementation proves its capability to be used for programs with high complexity and machine resource requirement. Cloud Based Serverless computing is an ever evolving technology and this initial research lays down the ground for further enquiry into cloud architectures for deployment on commercial two-wheeler applications in real-time.

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