ABSTRACT

Growing concern over the environmental impacts and oil-dependence has prompted the investigation of alternate propulsion technologies for motor vehicles. Recently, plug-in hybrid technology has emerged as one of the promising alternatives to reduce petroleum consumption and vehicular emissions. Two-wheelers are an important mode of transport option in urban India and their high fuel consumption and emission contribution needs to be attended to improve the air quality.

This work attempts to study the benefits of plug-in hybrid technology for two-wheelers with a suitable retrofitting to a scooter. Simulation of energy and power requirements with a given driving cycle was carried. In addition, the battery mass required and the cost to meet the power by battery alone were also estimated. In order to estimate daily average travel distance of two wheelers, a survey was conducted in the Coimbatore city. Based on the survey, a control strategy has been proposed to suit the heterogeneous city traffic pattern. The control strategy is to run the vehicle on three modes of operation, namely, electric mode, hybrid mode and engine mode. In the electric mode, the motor-battery combination is designed to meet the daily travel range within the city. Hybrid combination helps to eliminate the idling and low power operations of internal combustion engine and to improve the fuel economy and reduce emissions.

A 100 cc two-wheeler was chosen for the purpose of the study and a hub motor was fitted to the front wheel. A battery pack was installed separately for power supply to it. An experimental test was carried out to study the performance of the selected hub motor and IC engine for various combinations of running for the purpose of validation of the selected control strategy. These performance characteristics were compared with that of the standard driving cycle simulation results. An IDC simulator kit was developed and fitted to the vehicle to study the energy consumption and power split between energy sources. The all-electric drive for the plug-n hybrid electric two-wheeler (PHETW) is about 27.2 km in IDC road test, whereas the vehicle actually covered 23.4 km in actual city road test. For the hybrid mode, the motor-to-engine and engine-to-motor change over set-speed limit has been proposed by compromising between fuel consumption and travel range. In hybrid mode, the retrofitted vehicle (PHETW) is 2.48 times more fuel efficient when compared to a base vehicle without retro-fitment. The simulation results were compared with that of the actual road test results and the deviation was found to be about 13.4%.

Primarily, the challenge of designing a plug-in hybrid electric two-wheeler lies in identifying the all-electric range suitable for daily travel needs of the customer. This work mainly focuses on fixing the all-electric range for the given driving cycle to estimate the battery energy capacity, additional mass and initial investment cost with respect to the three main types of traction batteries namely the lead-acid, nickel-metal hydride (Ni-MH) and lithium-ion (Li-ion). The simulation model developed in this work can

provide information on both the designing of all-electric range and sizing of the battery pack. Three driving cycles namely, the European driving cycle - ECE R40 (to represent international urban driving pattern), the Indian driving cycle – IDC (to represent national driving pattern) and a city driving cycle – CDC (to represent local city driving conditions) were considered for the purpose of this study. The city driving cycle demands 19% and 27 % more energy than IDC and ECE R40 respectively. The estimated battery energy capacity varies linearly with the all-electric range (AER), whose slope is a function of battery mass. This study results can also be used for estimation of all-electric range for similar categories of two-wheelers in India.

The economic analysis indicate that the initial cost of Ni-MH batteries seen to be on the higher side for the desired electric drive range, whereas the life cycle cost is much lower when compared to the use of Li-ion and lead-acid batteries. Ni-MH batteries are more economical and suitable for implementing in plug-in hybrid electric two-wheelers.

The present work also estimates the level of annual petrol saving and CO_2 (Carbon dioxide) emission reduction from the two-wheeler segment in India. An emission model has been used to forecast the annual petrol saving and reduction of CO_2 emission from the two-wheeler segment. By replacing all IC engine two-wheelers with electric two-wheelers about 48% CO_2 emission reduction could be achieved. With the plug-in hybrid electric two-wheeler it was around 37%. Hence, retrofitting the existing two-wheelers can also bring down the fuel consumption and emission levels to a large extent.

As the two-wheelers contribute to two-thirds of the total vehicle population in India, the implementation of plug-in hybrid concept for the existing two-wheelers may save a large quantity of petrol with little consumption of electricity. If this electricity can be produced by renewable sources like solar, wind, hydro, etc. then it will save consumption of imported petrol to a large extent.