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Comparative Study of Energy Consumption for Electric Vehicles with Various On-board Energy Storage Systems

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Abstract

Electric vehicles are driven by traction motor with intermittent load characteristic. The use of appropriate batteries type is a crucial factor resulting in energy consumption, battery sizing and vehicle design. This paper focuses on the comparison of energy consumption of the electric vehicles in three different energy storage systems consisting of lead-acid battery, lithium-ion battery and hybrid energy storage system (HESS) incorporating with lithium-ion battery and ultracapacitor. The mathematical approach is used to simulate three route vehicle movement which are i) New York city cycle (NYCC), ii) UN/ECE reg. 83 or extra-urban driving cycle and iii) field measured driving profile in Bangkok. Sequential quadratic programming (SQP) is employed to find optimal weights of the energy storage system. The simulation results were consistent for all three routes. The lead-acid battery is heaviest weight but highest energy recovery from the regenerative braking and the energy consumption is greatly different from the others.

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Keywords: Electric vehicles simulation; Hybrid energy storage; Regenerative braking

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1. Introduction

Nowadays, the energy storage system plays important role in electric vehicles. The batteries are still the main energy source for electric vehicles. Due to its high specific energy compares to other energy storage devices as illustrate in [1-6]. A number of life cycles and specific energy are more technologically advanced. However, there seem an inadequate power density to supply the intermittent traction loads with suddenly high power requirements. The batteries are not appropriate to be charged or discharged as suddenly as ultracapacitors. It also has a shorter lifespan than ultracapacitors, especially when it uses with high current. Overcharging and overdischarging may cause of over temperature and safety issue. To supply the fluctuated load, the batteries of electric vehicles seem to be oversizing design.

The main study presented in this paper aims to compare the study of energy consumption for electric vehicles with three differents on-board energy storage systems. The NYCC is the driving information in New York city cycles route, USA, where vehicles run at low speeds and also stop and accelerate frequently. NYCC is used as a test route 1 in this research. Test route 2 and 3, in which UN/ECE reg. 83 is applied to represent in extra-urban driving cycle route and a bus transports of the Provincial Electricity Authority (PEA) employees to work, are PEA headquarters-Samakkee road route, respectively. Besides, the speed profile of the test routes and altitudes obtained from the global positioning system (GPS) is used to estimate a gradient. Three different types of energy storage system, including lead acid, lithium-ion and hybrid energy storage system incorporating with lithium-ion battery and ultracapacitors are compared. Energy storage weight optimization is applied under regenerative braking condition. Finally, the lead-acid battery, lithium-ion battery, and lithium-ion battery-ultracapacitors hybrid storage system (HESS) have been used in the simulation for each route and their important parameters were compared.

This paper organizes a total of five sections. Next section, Section two, illustrates the brief of traction performance and vehicle movement simulation. Section three gives the optimal energy storage weight calculation. Section four is the section describing simulation results and discussion. Conclusion remark is in the last section.

2. Traction performance calculation

In this section mathematic modeling is applied to describe characteristics of vehicle movement and to find the power consumption of electric vehicle. The vehicle mechanical power consumption by tractive force multiplying with velocity is described in (1).

$$P_v = F_t v \tag{1}$$

Where P_v is vehicle's mechanical power consumption
v is vehicle's velocity
F_t is vehicle's tractive effort

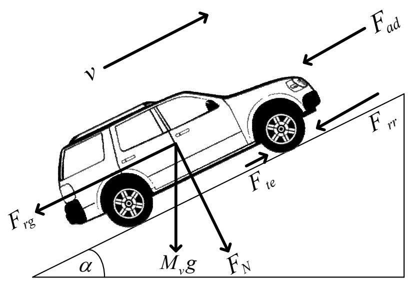

Fig. 1. Free-body diagram of a vehicle on a gradient.