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OPTIMAL COMPONENT SIZING AND CONTROL OF A MULTI-SOURCE ELECTRIC VEHICLE BASED ON AN IMPROVED OPTIMIZATION ALGORITHM AND A NOVEL ENERGY MANAGEMENT SYSTEM

by

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Abstract

Electric vehicles (EVs) are considered the ultimate solution for a sustainable transportation alternative to reduce the global warming and energy crisis. The public's perception of EVs is still adverse despite advancements in EV technology because of issues with driving range, high initial costs, the added weight of the energy source, and an unpredictably short lifespan of the EV system. To administer the same performance as compared to modern fossil fuel-based vehicles, hybridization of multiple energy sources is significant for EVs. The most pressing issues with multi-source EVs are optimum source sizing and regulating power flow from hybridization sources with the appropriate converter topologies, controllers, and energy management system. To address these issues this work focuses on the optimal sizing of EV source system and the real time control of EV with multiple sources. After a thorough assessment of source properties and a review of dynamic source behavior, an adaptive energy management system (AEMS) is advised for the optimal source sizing of EV. Next, a weighted multi-objective function that incorporates the investment cost, hybrid source weight, running cost, and source degradation is used to define the optimal sizing problem. To solve this optimal sizing problem, the butterfly optimization algorithm (BOA) is improved based on chaos theory, quantum computing, and adopting a ranking strategy to maintain a balance between the exploration and exploitation phases of the particle searching technique. By contrasting the modified BOA with BOA and other optimization techniques, the effectiveness of the algorithm is evaluated using several benchmark functions. When compared to other algorithms, the enhanced BOA performs better. The performance of AEMS is validated by comparing the optimized storage size of EV generated using discrete wavelet transform (DWT) energy management. The AEMS outperformed the DWT technique when taking into account the battery-ultracapacitor hybrid source's investment cost, with a devaluation of 22.5% for the urban dynamometer drive cycle and 20% for the Artemis drive cycle. To execute the EV power train control model using the proposed AEMS, non-inverting H bridge buck-boost converters are used while accounting for the dynamics of output voltage from two different energy sources as well as charging and discharging characteristics of EV. To meet the demands for speed and load torque while taking into account the non-linear traction motor characteristics and other system disturbances, a non-linear state feedback controller (NLSFC) with disturbance observer is recommended for the speed controller. A comparative analysis is performed with PI controller to assess the performance of NLSFC controller. When the proposed NLSFC is used, the outcome improves, with steady-state error dropping from 0.43 to 0.0014 and peak overshoot dropping from 12.07% to 3.51% during system acceleration. In addition, the hardware prototype of the hybrid EV with the proposed non-linear controller and H-bridge converter is developed. The hardware prototype is also put through its paces with various motoring and regenerative braking scenarios. The outcome effectively demonstrates the system's speed and torque follower properties. The outcomes of this thesis support the viability of dynamic energy management techniques designed to create a hybrid EV system with a low cost, light weight, minimal source degradation and less pollution. This is in accordance with progressing UAE Green Mobility initiative, including the Dubai Clean Energy Strategy and the UAE net zero by 2050 strategic initiative which aims to achieve climate neutrality by 2050 with an effective role in climate control issues Furthermore, the output of the simulation and the hardware results also demonstrate how well the converter, converter controller, and speed controller follow the required speed and torque from the consumer side.

Keywords: Hybrid electric vehicle, adaptive energy management, optimal source sizing, real time control, non-linear state feedback controller