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RESEARCH ARTICLE

Energy Management Strategy for Hybrid Energy Storage - Electric Vehicles Based on Intelligent Controllers

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ABSTRACT

Developing an Energy Management Strategy (EMS) that takes into account the Electrical Vehicle's (EV's) power distribution between the battery and ultracapacitor helps lessen the EV's power usage and prolong battery life. Therefore, the goal of this paper is to create a Fuzzy Logic Controller-based EMS for EVs that takes battery degradation into account. The hybrid energy storage electric vehicle model is developed first for EMS verification. Battery deterioration modelling trials are complete in the meantime. After that, a Hybrid Energy Storage System's (HESS) power is distributed sensibly using a rule-based control strategy. By comparing the proposed EMS to the existing EMS and the findings, it becomes clear that the former uses less energy and causes less battery degradation. The features of the HESS serve as the basis for the experiment's design, execution, and modelling of battery deterioration. Based on the model, the proposed work tested in MATLAB/Simulink a rule-based EMS and a PMP energy management method that takes battery degradation into account. Considering battery deterioration, the limited energy of hybrid energy storage electric vehicles is divided equitably and utilized to maximize energy management.

Keywords: electric vehicle; hybrid energy storage system; energy management strategy; fuzzy logic Controller; battery degradation

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INTRODUCTION

The research and development of hybrid energy storage systems, which can increase the efficiency and power of electric vehicles, has been receiving greater attention recently. Both batteries and ultracapacitors play significant roles in a hybrid energy storage system. Lithium-ion battery shortages can be mitigated by using ultracapacitors because of their high-power density, rapid charge and discharge times, and multiple-cycle life [1]. On the other hand, the battery's power and efficiency would gradually degrade over time due to electrochemical processes and the battery's state [2]. In addition, the energy management system in a hybrid electric vehicle is responsible for controlling and balancing the power supplied by the car's power battery and ultracapacitor [3-4]. To maximize vehicle efficiency and prolong battery life, the energy management system must take battery degradation into account while providing the required power. Consequently, the primary difficulty of an energy management approach for hybrid energy storage electric vehicles is figuring out how to fairly divide the power from the power battery and the ultracapacitor. Hotspots in the study of energy management for hybrid energy storage electric cars include the design of energy management strategy, the construction of the battery decay model, and the matching of ultracapacitors and DC/DC converters. Battery ageing factors have been the basis for numerous models published by domestic and international academics depicting the decline in battery life and performance over time. The evaluation models are used to offer energy management techniques that take battery degradation into account [5].There are now three types of models used to describe the decline in lithium-ion battery capacity: mechanism models, equivalent models, and empirical models. The physical and chemical features of the battery provide the basis for the mechanism model, which aids in the investigation of the causes of battery capacity loss. Mechanism models are typically employed in battery research rather than control problems [6] due to the complexity of the model creation procedure and the difficulty of acquiring the electrochemical parameters included in the model. The correctness of the equivalent circuit model is affected by several external factors, and the electrical components are susceptible to losses.

The model accuracy requirements of this investigation can be met with the use of an empirical model, the establishment and computation of which are, however, rather straightforward [7]. Considering the battery capacity decline and the physical interaction of many parameters, a considerable amount of test data on battery life is employed for formula-fitting construction [8]. Battery state of charge, state of charge, and ultracapacitor state of charge are all examples of inputs. When discharging a battery or capacitor, the power is determined by the battery power distribution coefficient. Although this management strategy's foundation is straight forward to pick up, the control principles behind it necessitate extensive expertise. Complete utilization of composite power supply with pinpoint accuracy is unachievable. An onboard lithium-ion battery system's thermal safety and degradation were highlighted in recent research [9] that offered a universal algorithmic framework integrating a model-based state observer and a deep reinforcement learning-based optimizer. Rapid charging, thermal safety enforcement, increased battery life, and computational tractability are all areas where it has proven itself better. Optimizing energy management in rechargeable hybrid energy storage electric cars was the focus of [10], which also offered a battery model. This model predicts the rate of decline in battery health as the state of charge (SOC) and pack temperature are changed. The numerical multi-objective optimum control problem is solved by using SDP and PSO to strike a balance between power consumption and battery life while meeting the needs of the vehicle. Efficiencies in battery life and power consumption were analyzed.

Hybrid Energy Storage Electric Vehicle Modelling

In this paper, a closer look at the parallel hybrid energy storage system (HESS) is shown in Figure 1 which consists of a controller, motor, and ultracapacitor in addition to a battery and a DC/DC converter.

Vehicle Modelling

In order to simulate a hybrid electric car, it is necessary to analyze a simulation experiment involving energy management. That's why this research constructs a model car, complete with a driver model, a vehicle longitudinal dynamic model, a motor model, and a HESS model. While the other models are constructed using mathematical modelling, the motor model is generated by utilizing simulation results. In this paper, the UC module is connected to the DC bus via a bidirectional DC/DC converter, while the battery module is connected directly to the DC bus, resulting in a UC semi-active hybrid topology. The DC/DC converter can regulate the UC's output power to deliver the maximum amount of energy to the vehicle while keeping the system's overall power consumption to a minimum.

While the other models are constructed using mathematical modelling, the motor model is generated by utilizing experimental methods. In this research work, the UC module is connected to the DC bus via a bidirectional DC/DC converter, while the battery module is connected directly to the DC bus, resulting in a UC semi-active hybrid topology. Also, the DC/DC converter may regulate the UC's output power to deliver the vehicle's maximum power while minimizing the system's overall power draw and extending the battery's service life. The HESS model is calibrated using the battery, UC, and DC/DC factors and characteristics. It is the Rint equivalent circuit that is chosen by the battery model. The model's power battery has an open circuit voltage and internal resistance that vary with state-of-charge (SOC) and temperature, and whose values can be determined with experimentation. Power in the HESS is managed by a buck-boost bidirectional DC/DC converter, and a model of this converter is developed based on its operating principle and specifications.

Energy Management Strategy Based on Fuzzy Control

In energy management strategy, the primary function is to regulate power distribution in hybrid electric vehicles and all other electric vehicles that are operated with battery management. As a rule-based control approach, fuzzy control is very flexible and reliable. An important problem in developing energy management strategies is figuring out how to maintain the battery operating conditions in its optimal discharge state. Distribution of the discharge current from the battery and ultracapacitor will accomplish this purpose. It is possible to test the efficacy of the approach by plugging the multiplier for dispersed current into a battery decay model and determining the resulting battery decay rate. In this paper, the notion of the power distribution coefficient K symbolizes the importance placed on battery power, and picking the vehicle demand power, the ultracapacitor SOCuc, and the battery SOCb to achieve the best possible power distribution ratio. This allows for an examination of the fuzzy controller's power distribution coefficient.

$$K = \frac{P_b}{P_{req}} \qquad (1)$$

$$P_b = P_{req}(1 - k) \qquad (2)$$

where battery power (Pb), UC power (Pc), and vehicle power demand (Preq) are all inputs to the equation.

Based on the hybrid energy storage electric vehicle's operational characteristics, the following control ideas can be derived: when the required power is positive, the hybrid energy storage system outputs power; on the one hand, the ultracapacitor is used to protect the battery from discharging smoothly; on the other hand, it provides instantaneous power to the drive motor. Hybrid energy storage systems can recover energy whenever the power demand is negative. The ultracapacitor restores energy lost as a result of braking, and it also shields the battery from the destructive effects of high-current shocks. Power levels and amplitudes, as well as the emphasis placed on regulation, are distinct between the two modes of operation. It is necessary to design separate control methods for the two modes of operation of the composite power supply. Using the control concepts, it may categorize the control approach into two modes: driving and braking. Fuzzy controller 1 fairly divides the power during the discharge phase, and fuzzy controller 2 determines the charge phase power distribution.

Control Method

FLC evaluates input data in terms of logical variables with continuous values ranging from zero to one. The operation of the controller in a fuzzy logic control system is based on fuzzy rules generated using fuzzy set theory. Figure 3block diagram of Fuzzy logic controller. The fuzzification, defuzzification, input, and output variables make up FLC. The fuzzy sets are formed using seven membership functions for the inputs error E, change in error CE and the output (P_{loss}) are shown in Figures5 and 6 and Figure 4 depicts the output.

Simulation Results

Figure 5 depicts the ideal power distribution of the HESS with two distinct energy management strategies under UDDS operating conditions, demonstrating that both strategies can efficiently divide the power of batteries and the ultracapacitor. According to the findings, the PMP energy optimization management technique outperforms the fuzzy control strategy in terms of controlling battery degradation. The optimization method reduces the battery's peak current by 29.5 A, the cell deterioration rate after 300 cycles by 2.33 percent, and the energy consumption rate by 11.72-kilowatt hours per 100kilometers. To sum up, hybrid electric vehicles that employ a PMP-based energy management system that takes battery deterioration into account can significantly postpone battery decline and energy usage, save energy, and protect batteries.

CONCLUSIONS

The purpose of this work is to present an FLC-based energy management approach for hybrid electric vehicles that takes battery degradation into account, with the end objective of assessing the effect of battery decline on the power and economic benefits of electric vehicles. The hybrid electric vehicle model was first established to ensure the strategy's success. To prevent the battery from degrading too quickly and keep the vehicle's power performance stable, the fuzzy control method is utilized to intelligently divide the load between the ultracapacitor and the battery. Lastly, the proposed control method is verified using simulation.

REFERENCES

1. Fengyan Yi, Dagang Lu, Xingmao Wang, Chaofeng Pan, Yuanxue Tao, Jiaming Zhou,Changli Zhao. "Energy Management Strategy for Hybrid Energy Storage Electric Vehicles Based on Pontryagin's Minimum Principle Considering Battery Degradation", Sustainability, 2022.
2. G. Sravanthi, T. Rama Subba Reddy, K. Mercy Rosalina. "Solar PV Integrated UPQC to Enhance Power Quality Problems of Distribution Power System Using Fuzzy Logic Controller", 2023 World Conference on Communication & Computing (WCONF), 2023.
3. R. Manivannan. "Research on IoT-Based Hybrid Electrical Vehicles energy management systems using Machine Learning-based algorithm", Sustainable Computing: Informatics and Systems, 2023.
4. Wei Zhou, Ziqi Zeng, Shijie Bao. "Intelligent Ventilation Management System of Laboratory Based on Fuzzy Logic", 2023 9th International Conference on Control, Automation and Robotics (ICCAR), 2023.
5. Saman Nasiri, Mostafa Parniani, Saeed Peyghami. "A multi-objective optimal power management strategy for enhancement of battery and propellers lifespan in all-electric ships", Journal of Energy Storage, 2023.
6. Wei Du, NikolceMurgovski, Fei Ju, Jingzhou Gao, Shengdun Zhao. "Stochastic Model Predictive Energy Management of Electric Trucks in Connected Traffic", IEEE Transactions on Vehicular Technology, 2022.
7. Hao Li, Haiqing Yang, Xingyue Li. "Investigation on the working performance of a non-dispersible grouting material for the crack repairment of underwater structures", Construction and Building Materials, 2023.
8. Rodolfo E. Haber. "IEEE Transactions on Systems Man and Cybernetics", Part C (Applications and Reviews), 9/2007.
9. Mehmet Kubilay Eker, Ismail H. Altas. "A Fuzzy Voltage Regulator (FVR) for a Stand-alone Synchronous Generator", Electric Power Components and Systems, 2007.

10. Acharjee, P, and K Ali. "Load flow analysis using decoupled fuzzy load flow under critical conditions", International Journal of Engineering Science and Technology, 2011.

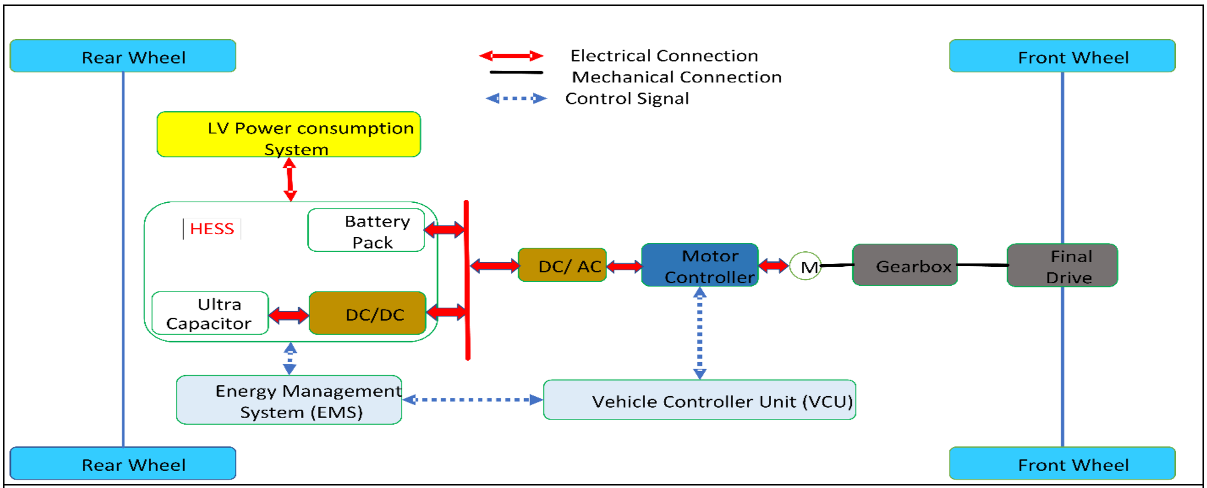

Figure 1. The configuration and detailed structure of a parallel hybrid electric vehicle.

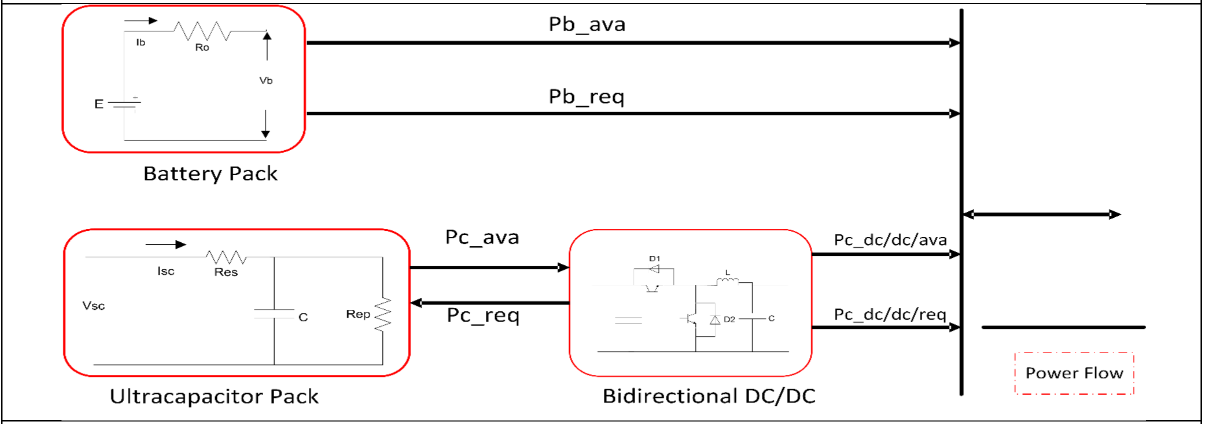

Figure.2 Modeling of Hybrid Energy Storage System

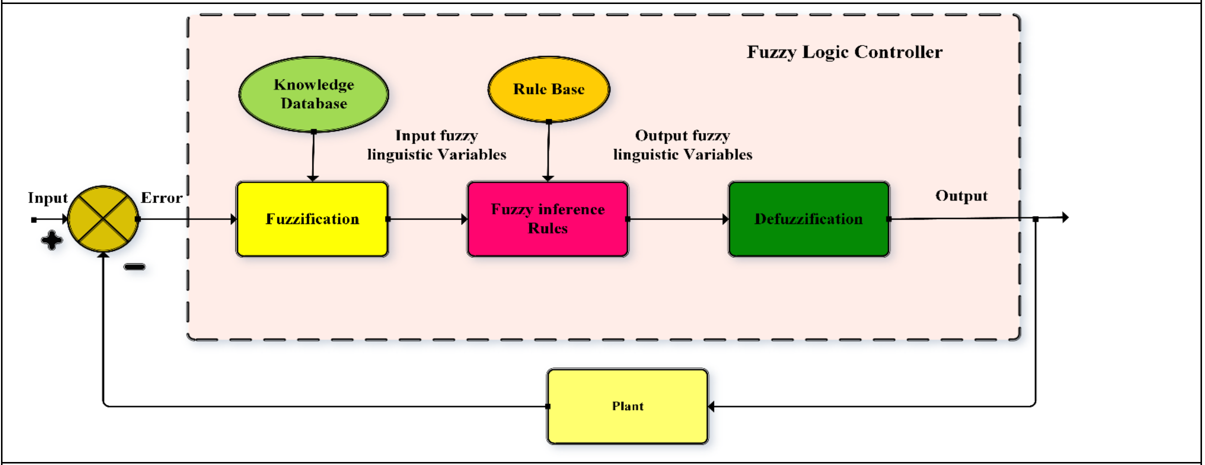

Figure 3.Block diagram of Fuzzy logic controller

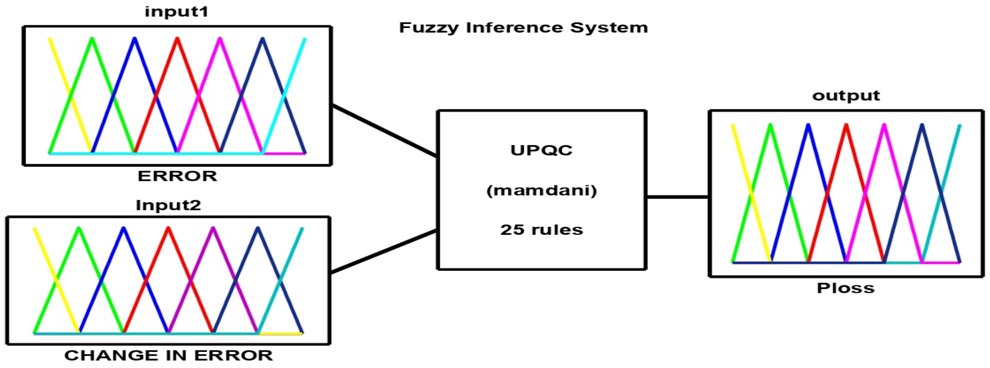

Figure 4. Fuzzy inference System

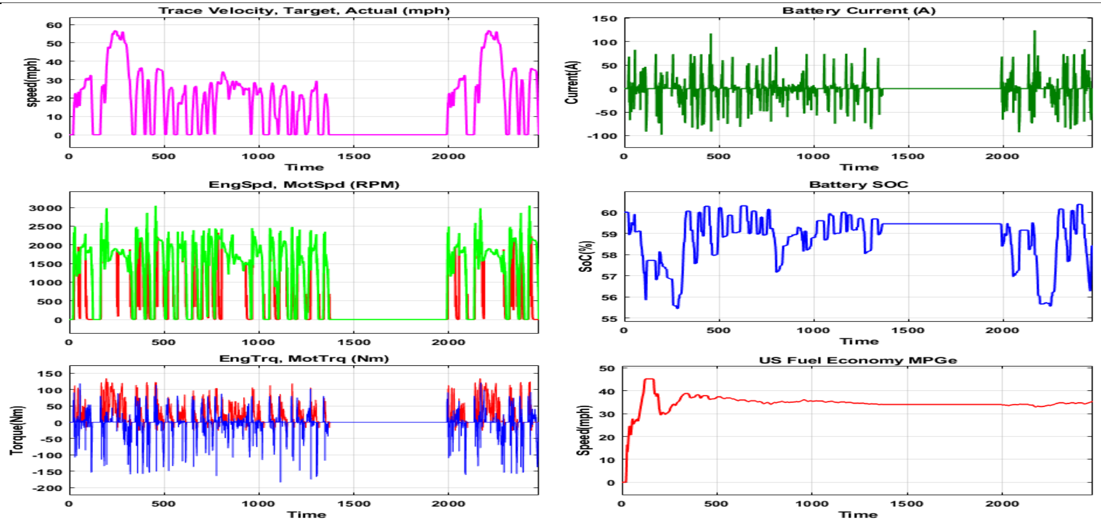

Figure 5. Result curve of speed and power distribution for the fuzzy control strategy.

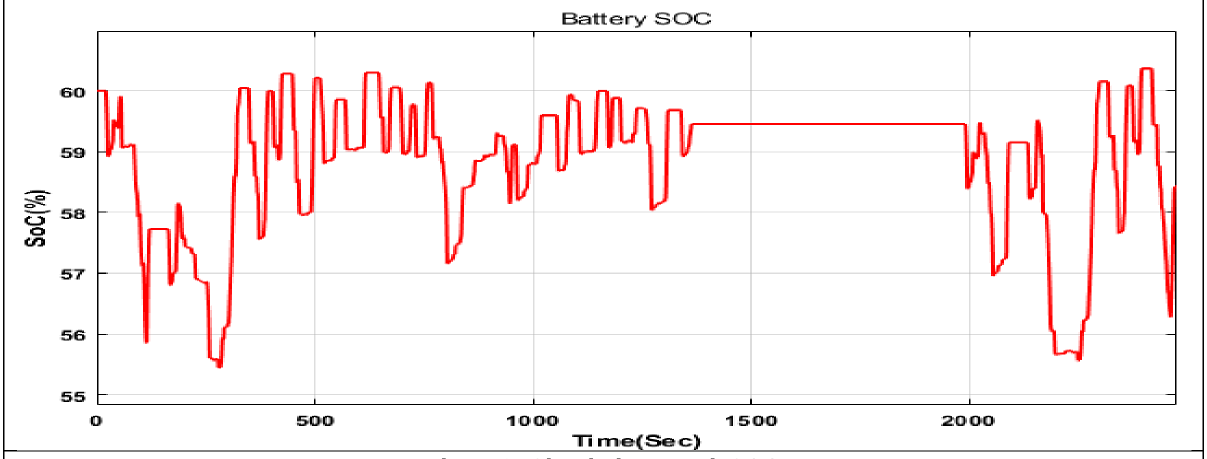

Figure 6. Simulation Result SOC