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A Modelling Of a Battery Chiller for Analysis of Thermal Management System of Heavy-Duty Fuel Cell Electric Vehicles

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Extended Abstract

Hydrogen fuel cell electric vehicles (FCEVs) are increasingly recognized as sustainable and zero-emission transportation solutions, particularly for heavy-duty applications [1]. One of the primary challenges in integrating fuel cell and battery systems is heat rejection and maintaining optimal operating temperatures, especially for the battery pack, which is prone to excessive heat generation during sudden load changes. Effective thermal management is essential to ensure system efficiency, performance, and longevity [2]. This study focuses on developing and evaluating a thermal management system specifically designed for the battery pack in heavy-duty FCEVs. The proposed system ensures the battery pack operates within its optimal temperature range of 20°C to 40°C, with a maximum allowable temperature difference of less than 5°C [3].

Among various thermal management approaches, the indirect liquid cooling method utilizing a heat pump system – commonly referred to as a chiller system – has demonstrated superior effectiveness in maintaining optimal battery temperatures, even in high-temperature environments [4]. In this study, the battery chiller system and its components were modeled and simulated using MATLAB/Simulink. The system consists of an electric compressor, a flat-tube louver-finned condenser, an expansion valve, a plate evaporator, a coolant pump, and a battery cooling plate. The refrigerant used is R-134a, and a water-glycol mixture serves as the coolant. Thermodynamic properties of R-134a were obtained from [5], and heat transfer coefficients were calculated using established empirical correlations [6], [7].

To evaluate its performance, the chiller system was integrated into a fuel cell electric city bus model, which includes a complete power supply system consisting of a fuel cell system and a battery pack, along with specifications typical of a city bus. The vehicle model was dynamically simulated using the World Harmonized Vehicle Cycle (WHVC) driving profile, capturing transient effects such as battery heat generation during rapid acceleration and heat extraction via the chiller system.

Results show that the proposed thermal management system maintains the battery pack at a stable temperature of approximately 25°C throughout the simulation. While the system effectively handles thermal loads, sudden changes in battery load during charging/discharging caused temperature fluctuations, with a maximum temperature of around 30°C and a minimum of approximately 23°C. These fluctuations result from abrupt load changes but quickly stabilize around the desired 25°C, meeting the system's performance objectives.

In conclusion, the proposed battery chiller system effectively addresses the critical thermal challenges of heavy-duty FCEVs. It demonstrates robust and reliable performance under dynamic conditions, making it a promising solution for future applications. Further research should focus on optimizing energy consumption and evaluating system performance under extreme environmental conditions to enhance its applicability.

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