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CONNECTED AUTOMATED VEHICLES AND ITS, ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, VEHICLE DYNAMICS AND CONTROL

Novel Electric Vehicle Powertrain of Multi-stack Fuel Cell Using Optimal Energy Management Strategy

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Abstract

Fuel Cell Electric Vehicle (FCEV) powertrain layouts and control strategies have historically overlooked the asymmetric energy storage effect, despite its significant impact on system efficiency. In this study, we propose a novel FCEV powertrain layout using dual fuel cells to uncover hidden fuel efficiency improvement factors in comparison with the conventional Single Fuel Cell System (SFS). To address the issues of low efficiency operation in SFS and the limitations of existing energy management strategies that hinder high output performance, we present a minimum efficiency-based power control strategy. Additionally, we implement a partial system operation strategy to optimize efficiency according to the state of the power sources. This combined approach results in substantial improvements in both hardware and software efficiency, a possibility that was not previously achievable. Through this research, we demonstrate the potential for enhancing the fuel efficiency of the multi-stack system, a concept that has not been implemented yet. Moreover, we propose a new direction for the architectural design of FCEVs that overcomes the limitations of the SFS, thereby addressing potential malfunctions.

Keywords Fuel Cell Electric Vehicle · Multi-stack system · Particle Swarm Optimization · Power Distribution Algorithm · Co-simulation · New powertrain

List of Symbols

T_{mot}	Motor torque, N
ω_{mot}	Motor angular velocity, rad/s
V_{bus}	DC bus voltage, V
I_{mot}	Motor current, A
P_{loss}	Motor loss power, W
η_{fc}	Efficiency of fuel cell
SHV	Specific heating value of hydrogen, kJ/kg
V_{stack}	Voltage of the fuel cell stack, V
I_{fc}	Current of the fuel cell stack, A
$\dot{m}_{fc}$	Flow rate of fuel consumption, g/s
$V_{fc,cell}$	One fuel cell voltage, V
N	Number of cells
P_{aux}	Auxiliary system power, W
P_{stack}	Generated power of the fuel cell stack, W
γ	Ratio of specific heats of air
R	Gas constant of air
T	Temperature at the inlet of the compressor, K
p	Air pressure on the electrode surface,
p_0	Atmospheric pressure, atm
λ	Equivalent ratio of oxidant to fuel
W_O	Molecular weight of oxygen, g
$\dot{m}_{air}$	Flow rate of air, g/s
$\dot{m}_H$	Flow rate of hydrogen, g/s
x_B	Oxidant coefficient
ΔV_{gain}	Voltage gain
P_{gain}	Power gain
P_{dem}	Required power of fuel cell, W
$V_{OCV,cell}$	Open circuit voltage, V
R_{cell}	Internal resistance of the cell, ohm
SOC	Battery state of charge, %
V_{cell}	Battery cell voltage, V
I	Battery current, A
V_{bat}	Battery pack voltage, V
Q_{bat}	Battery capacity, Ah
q	Charge used by load, Q
η_{dis}	Discharge efficiency
η_{chg}	Charge efficiency

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