

ECMS-based Energy Management Strategy for a Hydrogen Fuel Cell Hybrid Yard Tractor

Juhan Lee¹⁾ Beomho Lee^{1)*} Taeho Park¹⁾ Dohyun Park¹⁾ Janghyeok Won¹⁾ Deokjin Kim¹⁾

1)Korea Automotive Technology Institute (KATECH), Virtual Design and Engineering R&D Center

303 Pungse-ro, Dongnam-gu, Cheonan, Chungnam 31214, Republic of Korea

*(*Corresponding author : leebh2@katech.re.kr)*

KEY WORDS: EV and HV systems, fuel cell, energy management, yard tractor, equivalent consumption minimization strategy, port duty cycle [A3]

Port yard tractors (YTs) combine a low average power demand with high transient peaks and long continuous duty, which makes hydrogen fuel cell (FC) hybrid powertrains an attractive zero-emission option for container terminals. The energy management strategy that splits the demanded power between the FC stack and the battery determines both hydrogen consumption and the loading imposed on the stack. This paper analyzes the rule-based supervisor of a prototype FC hybrid YT and proposes an equivalent consumption minimization strategy (ECMS) as a drop-in replacement for it.

A forward-looking simulation model of the FC hybrid YT was constructed, comprising an 80 kW gross FC stack rated at 74.6 kW net, a 78.5 kWh lithium-ion battery and a 310 kW traction motor. A representative duty cycle was derived from 191 in-service trips of two LNG-powered YTs by selecting the trip whose mean driving speed and relative positive acceleration are closest to the cohort median; four consecutive passes of that cycle represent a continuous 8.2 h work shift.

The rule-based supervisor holds the stack at its 31 kW lower saturation limit, which is the least efficient point of the admissible power range (Fig. 1). The proposed ECMS, implemented as an off-line-optimized two-dimensional command map that replaces the existing lookup table in place, relocates the median operating point to the 59 kW efficiency maximum and raises the mean power when running from 35.1 kW to 49.6 kW. The energy-weighted net system efficiency rises from 0.437 to 0.446, and charge-corrected hydrogen consumption falls by 1.4%, from 7,967 g to 7,853 g per shift, at essentially identical terminal state of charge. The peak rate of change of FC power falls from 365.2 kW/s to 5.0 kW/s, a reduction of 98.6%. The number of stack start-stop events increases, and a minimum dwell constraint of 240 s was found to minimize fuel consumption and stack cycling simultaneously.

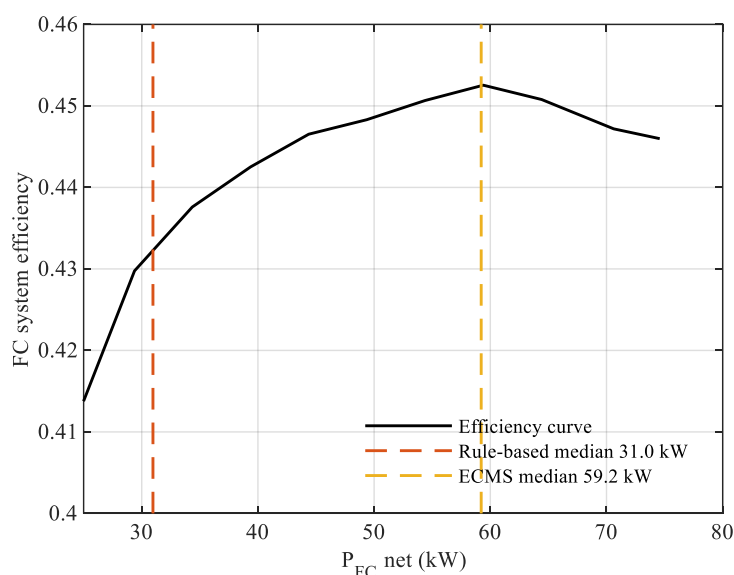


Fig. 1 Median FC Operating Points on the Net System Efficiency Curve

Relocating the FC operating point to the efficiency maximum of the stack therefore yields a modest fuel saving but almost eliminates the ramp-rate excursions of the baseline supervisor, while requiring no additional real-time computation in the vehicle control unit.

Acknowledgement: This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (No. RS-2025-02603170, Development and Demonstration of a Fuel Cell Power Pack for Clean Hydrogen Port Logistics Transportation Equipment (AGV, Yard Tractor)).