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Exergoeconomic analysis of a PEM fuel cell at various operating conditions

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Abstract

In this paper, a comprehensive exergoeconomic analysis of a 10 kW PEM fuel cell at various operating temperatures, pressures, cell voltages and air stoichiometries is performed. The analysis is performed at fuel cell operating temperatures (T/T_o) and pressures (P/P_o) ranging from 1 to 1.25 and 1 to 3, respectively. In addition, the calculations are performed on typical fuel cell operating voltages of 0.5 V and 0.6 V and at air stoichiometries of 2, 3 and 4 in order to determine their effects on the exergy cost of the fuel cell. The calculated results demonstrated the significance of the operating pressure, cell voltage and air stoichiometry on the exergy cost of the fuel cell. Furthermore, lower capital cost of the fuel cell, annual O & M cost and hydrogen cost could contribute to a drastic reduction in the exergy cost. Thus, a substantial improvement in the overall results could be achieved.

Keywords: PEM fuel cell; Exergetic efficiency; Exergy costing; Exergoeconomics

1. Introduction

Analysis based on the second law of thermodynamics, or sometimes referred to as exergy analysis, gives a true measure of a system's performance. Unlike energy analysis, which deals merely

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Nomenclature

ACC	annual capital cost, \$/kW yr
CRF	capital recovery factor, yr^{-1}
CF	capacity factor
i_r	interest rate, %
n_y	fuel cell lifetime, yr
C	exergetic cost, \$/GJ
$C^{O\&M}$	annual cost of operation and maintenance of fuel cell, \$/kW yr
C_{FC}	fuel cell cost, \$/kW
C_W	cost of exergetic power of fuel cell, \$/GJ
e	total exergy per unit mass, kJ/kg
$\dot{E}$	total exergy rate, kW
$\dot{m}$	mass flow rate, kg/s
$\dot{W}$	electrical power output, kW
T	temperature, K
T_o	standard temperature, 298.15 K
P	pressure, atm
P_o	standard pressure, 1 atm
V	cell voltage, Volts
Z_{FC}	total investment cost of fuel cell, \$/s
Z^{CI}	capital investment cost, \$/s
$Z^{O\&M}$	operation and maintenance cost, \$/s

Greek letters

ε	Exergetic efficiency
λ	Stoichiometry of air

Subscripts

air	air
H_2	hydrogen
H_2O	water
R	reactant
P	product

Superscripts

CH	chemical
PH	physical
FC	fuel cell

with the quantity of energy, exergy deals with both quantity and quality of energy [1]. Since exergy is a true measure of a system's performance, exergy costs should also be associated with the exergy