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Mathematical modelling and simulation analysis of advanced alkaline electrolyzer system for hydrogen production

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Abstract

As a result of increasing global energy demand, conventional energy sources such as coal, gas and liquefied petrol are being depleted at an alarming rate. An alternative way to overcome this is by applying renewable energy as a backup energy supply. One of the useful renewable energy technology used these days is the production of hydrogen from electrolysis. When combine with solar-PV or wind energy, Production of hydrogen from water electrolysis has the potential to play an important role as an energy carrier for future sustainable development. In alkaline electrolysis the electrochemical reactions possess energy barriers which must be overcome by the reaction species, this energy barrier is called activation energy and results in activation overpotential which are irreversible losses. The purpose for this work is to investigate the I-V characteristics of an advanced alkaline electrolyser. The main parameters such as ohmic overpotential, activation overpotentials (at anode and cathode) affecting the performance of the electrolyser were investigated. For this analysis, the equations related to fundamental thermodynamics and electrochemical reactions are model in MATLAB. In conclusion activation overpotential was observed to be higher by about 80 % compare with ohmic overpotential at the same current density.

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Keywords: Advanced alkaline electrolyzer; Mathematical modeling; Simulation; Renewable hydrogen; Activation overpotential

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1. Introduction

The continuous use of conventional energy sources poses tremendous challenges associated with pollution, greenhouse gas emission and climate change. As a result there is increasing global concern on the need to shift towards sustainable renewable energy system. In this perspective, renewable hydrogen has been recognized as a promising future energy carrier [1]. Hydrogen may be used as fuel in almost every application where fossil fuels are being used today, but without harmful emissions [2]. The Hydrogen may be converted into useful forms of energy more efficiently than fossil fuels. And despite public perception regarding hydrogen, it is as safe as other common fuels [3]. Hydrogen is not an energy source, and it does not occur in nature in its elemental or molecular form. Hydrogen is found most abundantly in water and this requires some amount of energy for the splitting process and because of the laws of thermodynamics, energy required to split water is higher than energy that can be released from produced hydrogen. Because of that, hydrogen is a convenient form of energy carrier just like electricity [4].

Nomenclature

Roman

A	area of electrode, m ²
ΔG	Gibbs free energy, J/mol
F	Faraday constant, 96485 C/mol
Q	volume flow rate, Nm ³ /h
T	temperature, K
V	cell voltage, V
n	number of cells
$\dot{n}$	production rate, Nm ³ /h
r	ohmic resistance parameter, Ωm^2
s	coefficient for overvoltage on electrodes, V
t	coefficient for overvoltage on electrodes, A-1m ²
z	number of electrons

Subscripts

H ⁺	hydrogen ions
H ₂	hydrogen gas
H ₂ O	water
O ₂	oxygen gas
OH-	hydroxide
aq	aqueous
g	gaseous
l	liquid
rev	reversible
act	activation
ohm	ohmic

Greek

η_F	Faraday efficiency
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Acronyms

DC	Direct current
KOH	potassium hydroxide
NaOH	sodium hydroxide
NaCl	sodium chloride
GUI	Graphical user interface

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