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Using the hydrogen for sustainable energy storage: Designs, modeling, identification and simulation membrane behavior in PEM system electrolyser

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ABSTRACT

The objective of this paper is Modeling and simulation of electrolyzer model type proton exchange membrane (PEM) that it is connected with solar cells, for to define and identify the factors that influence the production of hydrogen and oxygen. To generate these types of gas, we have used water and a source of electricity generated by solar cells. To perform the simulations results by using MATLAB software. We have used different physical equations defining these types of problems (Nernst-Planck, Nernst –Einstein and Fick's law). The different results shown in this work, that these types of PEM are best suited for desert areas (Adrar) with high temperatures and solar flux. This study shows the influence of temperature on the various parameters (α,i_0, D and Q), and it also shows an electrolyzer equipped with a membrane produces a relatively large amount of hydrogen, volume up to 2.25 L compared with an electrolyzer cell without membrane, volume of 0.0001 L.

1. Introduction

Hydrogen is regarded as a potential carrier of the future energy. Solar hydrogen is hydrogen produced from renewable energy, including solar energy. This study provides a system ensuring the production of hydrogen by electrolysis of water with solar energy resources, that the Power is supplied by a solar chimney very simply, ecological and cheap. Adrar site has a good exporter of energy that is evident in Fig. 15–18, the solar fields are the highest in the world, sunshine duration in all the national territory outweigh almost 2000 h a year and can be up to 3900 h (highlands and Sahara). The energy available per day up to 05 kW per hour on most parts of the country or about 1700 kWh/m^2 per year in the north and 2263 kW/m^2 per year in southern countries. To reduce the phenomenon of global warming and climate change concerns the global efforts of the carbon dioxide concentration in the atmosphere. In this work we studied the factors that influenced the production of hydrogen. The aim of our work is to establish an effective method for hydrogen production using photovoltaic source. Several authors in [1–31] they presented their work on renewable energy system with hydrogen production, Where are touched the various scientific and economic studies in this range (Design, Techno-economic, optimization, realization). The work of Laplace [32] on the technology of H_2 and O_2 began in 1999 for fuel cells and PEM electrolyzer. The modelling of fuel cells and PEM electrolyzer Began in 2000 with the DRU Julian van der MERWE [33] developed during the thesis of Rémi Saisset [34] was clearly sitting in the thesis of Guillaume FONTES [35] and was extended to the fuel cell in the thesis of Marwan Zeidan [36]. The PEM electrolysers began in 2004 with the thesis of SAMER RABIH [37]. In lately the many authors [54–56] are Published some articles in range economic, hybrid energy storage and energy performance. The objective of this paper to study the model electrolysers get to know the most factors affecting the production of these gases and

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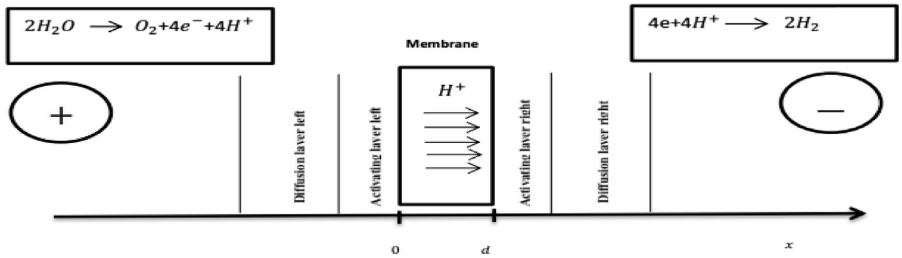

Fig. 1. Schematically the model.

combined the System electrolyser with PV to pave In future the experimental study in the Algerian Sahara.

2. Modelling and simulation

2.1. Modelling and design (PEM)

We studied the electrolyser type PEM, Where the basics of modelling are based on the Law of Butler-Vollmer, Nernst –Planck and Fick. The system that studied is composed of positive and negative electrodes, a membrane exchange cation and water. The external voltage supplied by a photovoltaic module. Fig. 1 Schematically describes this model.

2.2. Modelling assumptions

a The system studied is mono dimensional.
b The products of the reactions are perfect gauze.
c The current is supplied by photovoltaic cells.
d The electrolyte will be considered membrane exchange cation.
e The Mean pressures of the two gases are considered constant.
f The membrane is a good conductor of protons.
g The temperature considered is the average temperature within the component.
h The membrane is a good insulator of electrons.

2.3. Model electrolyzer

Electrolysis of water (Fig. 1) is the dissociation of water molecules into hydrogen and oxygen. A simple model was developed to explain the characteristics current potential of electrolysis-based charge, mass balance and the Butler-Volmer kinetics on electrode surfaces [38]. A full dynamic model based on the conservation of the molar balance with the anode and the cathode, that it has been developed. We have verified our model with experimental of [32]. The simulation of this study, including by five assistants: the membrane, voltage of PV cells, mass of water and storage volume. The parameters and the symbols used in the modelling are summarized in Table 1. All the electron transfer reactions are considered electrochemical oxidation and reduction Oxidation occurs at the anode, while the reduction occurs at the cathode. The anode and cathode side of the electrolyzer corresponds to the oxygen and hydrogen, respectively, the voltage between anode and cathode poles are calculated by equations as follows [52] (Table 2):

$$U = U_{re'v} + U_{diff} + U_{activ} + U_{mem} \quad (1)$$

With:

U: The electrolyzer voltage is equivalent to voltage of PV cells, so that less than two ($U < 2$).

$U_{re'v}$: Thermodynamics reversible voltage, the theoretical potential or the reversible voltage depends on the electrolyzer temperature and concentrations of the reagents on their reaction sites, that is to say, the catalyst/diffusion layer interfaces. The reversible voltage was directly dependent on the Gibbs energy (G); it changed by the electrochemical reaction:

$$U_{rev} = \frac{-\Delta G}{nF}. \quad (2)$$

The Gibbs energy from Nernst-Planck's law will be written:

$$\Delta G = \Delta G_0 - RTln\left(P_{H_2} P_{O_2}^{\frac{1}{2}}\right) \quad (3)$$

That we can write the relationship (2) under the following form

$$U_{rev} = \frac{-\Delta G_0}{nF} + \frac{RTln\left(P_{H_2} P_{O_2}^{\frac{1}{2}}\right)}{nF} \quad (5)$$

n: The number of electrons in the basic electrochemical exchange reaction (n = 2)

U_{diff} : is the voltage in the diffusion layer [53], the diffusion is a phenomenon of transport particles without macroscopic movement. This transport occurs initially in a system out of balance, the particle-rich regions to poor areas particulates, the diffusion stopped at current value, it is called the current limit (I_{lim}).

$$U_{diff} = -\frac{RT}{anF} ln\left(1 - \frac{I}{I_{lim}}\right) \quad (6)$$

I_{lim}: The limit current for diffusion
a : Transfer coefficient of diffusion layer
U_{activ}: is the activation voltage or DONNAN voltage, consider an exchanger in contact with a strong solution .the solution can penetrate the membrane but the concentration of against-ions

Table 1
Advancing chemical reaction.

Equation	$2H_2O2 \rightarrow 2H_2 + O_2$		
	Reactants	products	
	n_{H_2O}	n_{H_2}	n_{o_2}
initial state	$\frac{m}{18}$	0	0
intermediate state	$n_{H_2O} = \frac{m}{18} - 2y$	$2y$	y
final state	$\frac{m}{18} - 2y_{max}$	$2y_{max}$	y_{max}

Table 2
Parameters and symbols used in this modelling.

Nomenclature	Parameters and symbols
z	The valence of ion $2H^+$,2
α	Transfer coefficient,0.35 [32]
β	Transfer coefficient,0.16 [32]
d	Thickness of the membrane (m)
Q	Exchange capacity (M)
i_{lim}	limiting current of The reaction,117 A [32]
i_0	Exchange current,8E−7 A [32]
i_n	Internal leakage current of component,0.028A [32]
D	diffusion coefficient of the membrane, cm^2/s