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Modeling of an electrolyzer for a hybrid power supply system

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ABSTRACT

A PEM electrolyzer model described in the present communication is a component of a hybrid power supply system. It is developed using Matlab/SIMULINK.
Keywords: an electrolyzer, a proton-exchange membrane (PEM), a hybrid power supply system, Matlab.

INTRODUCTION

The basic disadvantage of photovoltaic and wind renewable energy sources is the fact that the maximum energy consumption and the renewable energy production periods do not always coincide. This reason generates the need of an additional energy source or a device which can store the produced and non-used energy. That will ensure all energy needs providing maximum energy consumption without concerning the renewable energy production. Another option is to use hybrid power supply energy through a subsystem. The latter must be able to compensate the difference between the produced and required energy and to steer each energy flow using energy management strategies [1].

One of the contemporary decisions uses fuel cells based on PEM (a proton exchange membrane) technology which provide electrochemical water partition to hydrogen and oxygen. Thus all redundant energy is transformed and stored as hydrogen [2]. This method has some advantages in respect to classic electrolysis – it ensures the production of a higher electric current density and a lower waste of power due to parasite capacitances [3].

Principles of PEM operation

The fundamental principal of PEM electrolysis is shown in Fig. 1.

It consists of two electrodes – an anode and a cathode powered by constant voltage. The water is passed to the anode, where a chemical reaction proceeds. The latter involves electrons withdrawal from the water molecule resulting in hydrogen ions and oxygen gas formation. The hydrogen ions pass through the PEM membrane to the cathode, where they receiving electrons form hydrogen molecules [4 - 6].

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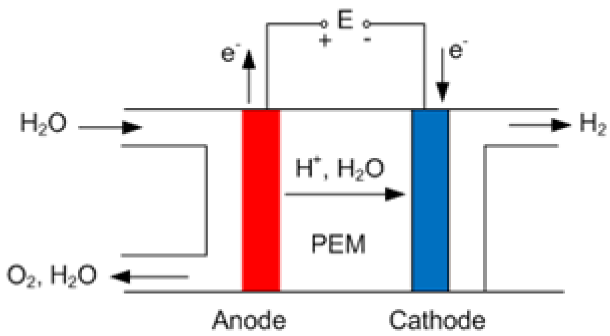

Fig. 1. Electrolyzer.

The chemical reactions describing the anodic and the cathodic processes are shown below:

$$H_2O - 2e^- = 2H^- + \frac{1}{2}O_2$$

$$2H^+ + 2e^- = H_2$$

The equation describing the electrolyzer`s work is as follows:

$$n_{H_2} = \frac{n_F n_C i_e}{2F} \qquad (1)$$

where n_{H_2} is the amount of hydrogen produced [mol s^{-1}], n_F is the Faraday effectiveness [-], n_C is the number of the lelctrolyzer's cells connected in series [-], i_e is the electrolysis current [A], while F stands for the Faraday constant (F = 9,6485.10^4 C mol^{-1}).

If electrolyzer work temperature is chosen and set to be -40°C, based on [7] the Faraday effectiveness can be calculated using the following equation:

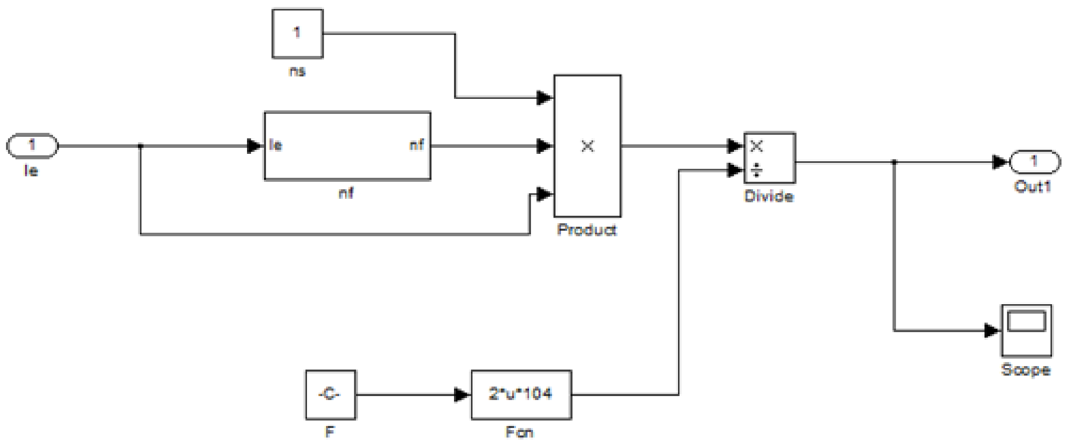

Fig. 2. General simulation model of electrolyzer.

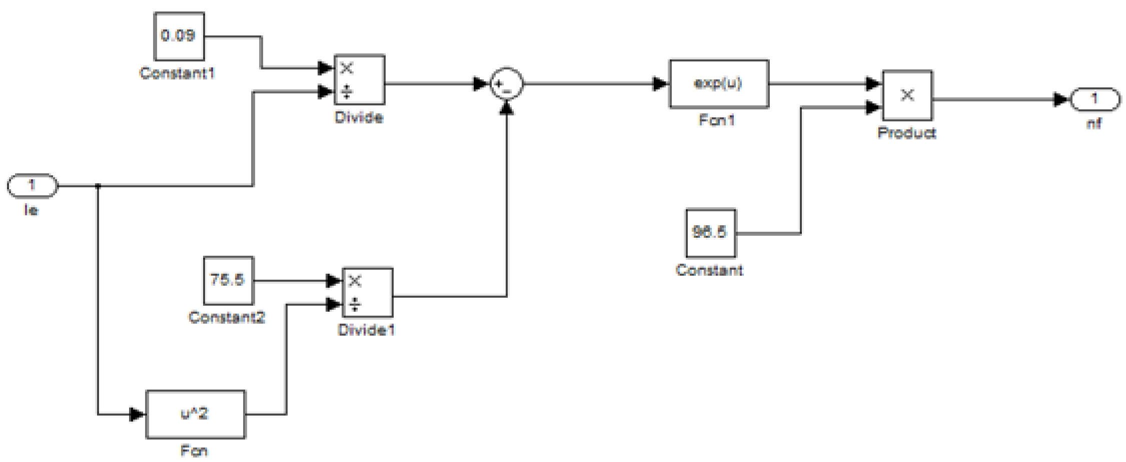

Fig. 3. Electrolyzer model subsystem for Faraday effectiveness determination.

$$n_F = 96.5 \exp\left(\frac{0.09}{i_e} - \frac{75.5}{i_e^2}\right) \tag{2}$$

A simulation model

A simulation model of a PEM electrolyzer is developed using Matlab/SIMULINK. It is based on Eqs (1) and (2). It is illustrated in Fig. 2 and Fig. 3. An electric current generated from a power photovoltaic array is used as an input signal changing in time.

The results obtained in the course of simulation of the hydrogen quantities obtained are presented in Fig. 4.

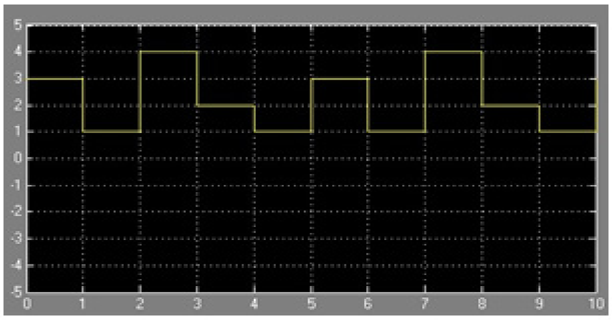

Fig. 4. Simulation results.

CONCLUSIONS

A model of a proton-exchange membrane (PEM) electrolyzer is developed by Matlab/SIMULINK as a component of a power supply system. Simulations are carried out and the amount of the hydrogen produced is determined.

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