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Model Experimental of Photovoltaic-Electrolyzer Fuel Cells as a Small-Scale Power

To cite this article: Y D Herlambang *et al* 2020 *J. Phys.: Conf. Ser.* **1700** 012100

Model Experimental of Photovoltaic-Electrolyzer Fuel Cells as a Small-Scale Power

Y D Herlambang[1], Kurnianingsih[1], Anis Roihatin[1], Fatahul Arifin[2]

[1]Politeknik Negeri Semarang
[2]Politeknik Negeri Sriwijaya

Email: masyusufdh@yahoo.com

Abstract. The purpose of this study is three to study the flow rates of H2 and O2 oxidants based on KOH concentrations at certain voltages, find the value of the best photovoltaic power at a particular test time, and find the value of fuel cells and improve the best photovoltaic-electrolyzer-fuel cell system based on calculations and the best time. The research method begins with studying the components of the PV electrolyzer and fuel cell, continuing experimental testing, and analyzing the research results. The results were obtained from the results obtained at 14.00 WIB. In electrolyzer testing, testing variations of 1 M, 2 M and 3 M molarity. The test results obtained the highest H2 and O2 gas flow rates at concentrations of 3 M, and the best efficiency at 1 M. From these data used for testing photovoltaic-electrolyzer systems -Fuel cell at 14.00 WIB with a concentration of 3 Molar, obtained the highest efficiency value of 1,847% with a power output of 2,184 Watt.

1. Introduction

Electricity consumption in Indonesia is now increasing with population and economic growth. Various power plants have been sought to fulfill these needs. However, most use fossil fuels whose availability is limited and produce emissions that can pollute the environment [1-3]. The above problems can be solved by utilizing more environmentally friendly renewable energy, such as solar energy, wind, fuel cell, and others. Renewable energy and environmentally friendly sources that have also been applied in Indonesia are fuel cells. Fuel cells are electro-chemical devices that convert chemical energy into electrical energy. Fuel cell fuels are hydrogen and oxygen with water output and do not produce emissions [4,5]. The fuel cell power plant has been built for the first time in Indonesia in 2012. The South Korean Government provides assistance in the form of power plant fuel cell capacity 300 kW to directly enjoyed Pemda DKI in Ancol which is directly shipped from South Korea for the US $3 billion. Hydrogen is clean energy so that the utilization of hydrogen energy in particular through fuel cell technology, in addition to increasing durability and energy independence is also expected to reduce greenhouse gas emissions. This can assist the Government in achieving a target reduction in national greenhouse gas emissions which has been targeted at 26% in 2020 [6,7].

Table 1. Research related to the job of PV Electrolyzer, and Fuel Cell

No	Researcher	Title	Results
1.	Rois A. R., Dr. Gunawan N.,	Analisa performansi dan monitoring *solar*	The power generated by photovoltaics and not used for the load will be used to

	S.T., M.T., Ir. Chayun B., M. Sc., rer.nat, 2016 [11]	*photovoltaic system (SPS) pada Pembangkit Listrik Tenaga Surya di Jawa Timur*	charge the battery, but the power can be saved to the battery compared to the remaining power of the PV generator that is not used for the load is 58%. Acquired PV efficiency of 5.20%
2.	Th. F. El-Shatter, M. N. Eskandar, M. T. El-Hagry, 2002 [12]	*Hybrid PV / fuel cell system design and simulation*	In summer photo-voltaic can produce power 11.299 kW/day. The resulting H2 can be stored in tanks for lower insolation rates on nighttime operations
3.	Yilanci, I. Dincer, H. K. Ozturk, 2008 [13]	*A review on solar-hydrogen / fuel cell hybrid energy systems for stationary applications*	The research conducted resulted in an optimal point of work on the 3 main components. Photovoltaic efficiency = 11.2%-12.4%. Efficiency Electrolyzer = 56%. Fuel cell efficiency = 30%-40%
4.	Dhanar Dwi Kuncoro, 2008 [14]	*Simulation of Proton Exchange Membrane Fuel Cell (PEMFC) as residential electrical power generation*	To obtain a maximum power of 3,500 watts required hydrogen gas of 234 grams/hour. While to produce a maximum power of 5,500 watts required hydrogen gas of 378 grams/hour. The efficiency of PEMFC achieved depends on the type of PEMFC design
5.	Wahyono, Yusuf Dewantoro Herlambang, Anis Roihatin, Budhi Prasetiyo, Totok Prasetyo [15]	Unjuk kerja sel bahan bakar hidrogen terhadap konsentrasi dan laju aliran bahan bakar	Open circuit voltage can vary in the condition variation of the fuel flow rate of 0.35 V. Besides the condition of the electrode surface will affect the current change. Low open circuit voltage will trigger the formation of air bubbles on the fuel line

Based on the results of the above studies, it is known that photovoltaic and fuel cells have relatively low efficiency. So, the research model of Photovoltaic-Electrolyzer-Fuel Cell as a small-scale power plant with innovations to utilize Photovoltaic as a source of power Electrolyzer and increase the molarity of electrolyte solution in Electrolyzer. So hopefully will be able to improve system efficiency. The performance of photovoltaic can be expressed in the form of a formula as the following input power, output power, and PV efficiency as follows [8]:

$$P_{in} = I_r \times A \;;\; P_{out} = V \times I \;;\; \eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Where, P_{in} is the input power (W), I_r is the radiation intensity (W/m^2), A is the surface area of the PV module (m^2), the Pout is the generated power of PV (W), V is the voltage (V), and I is the resurrected electric current (A). Electrolyzer has a reference that can be expressed in the following parameters: KOH electrolyte mass, hydrogen gas flow rate, electrolyzer input power, electrolyzer output power, and electrolyzer efficiency.

$$M = \frac{gr}{Mr} \times \frac{1000}{V_L}; \quad gr = \frac{M \times Mr \times V_L}{1000}; \quad \dot{m} = \rho \times Q; \; P_{in} = V \times I; \; P_{out} = \dot{m} \times LHV;$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Where, M is Molaritas, gr is the mass of KOH (gr), M_r is the mass equivalent (gr/mol), V_L is the volume of solution, m *(dot)* is the flow rate of hydrogen mass (kg/s), Q is the discharge of hydrogen (m^3/s), the P_{in} is the input power Electrolyzer (W), V is the measured voltage (V), I is a strong load current measured (A), P_{out} is the output power Electrolyzer (W), LHV is a Lower Heating Value (kJ/kg) and η is electrolyzer efficiency. Electrochemical reactions in the fuel cell are [9,10]:

Anode : $H_2 \rightarrow 2H^+ + 2e^-$

Katode : $\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Overall reactions : $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ + electrical energy + thermal

The parameters of the Fuel Cell are indicated by the fuel cell input power, fuel cell output power, and fuel cell efficiency.

$$P_{in} = P_{out} electrolyzer$$

$$P_{in} = \dot{m} \times LHV$$

$$p_{out} = V \times I$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Where, η is the efficiency of the fuel cell (%), the P_{in} is the input power of fuel cell (W), the P_{out} is the output power of fuel cell (W), m *(dot)* is the flow rate of hydrogen gas mass (kg/s), V is the measured load voltage (V), I is a strong load current (A) and the LHV is the Lower Heating Value (kJ/kg).

2. Research Method

The stages of this research include material selection, working and assembly of PV components, electrolyzer, and fuel cell. Further testing and analysis stage and discussion. The processing result is then displayed in the form of graphs of voltage-current and power-current characteristics. The performance of each of these components is examined and analyzed. Thus, it will produce a PV model Electrolyzer fuel cell with a variation in the flow rate of hydrogen fuel and the variation of fuel concentration that has the best performance.

This research will result in the flow rate of the fuel mass to fuel cell performance so that the parameters to be tested are the best concentration of electrolyte solutions to produce hydrogen discharge; Best photovoltaic output power produced as a source of energy, and current and voltage generated fuel cell with the photovoltaic source. In Fig. 1 showed that a wiring diagram testing circuit tool and the experimental of PV-electrolyzer fuel cell can be seen in Fig. 2.

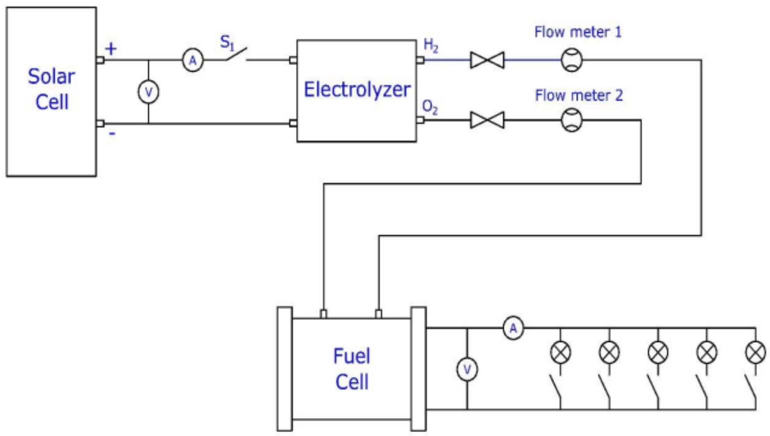

Figure 1. Photovoltaic-Electrolyzer-Fuel Cell testing circuit

Figure 2. Experimental of PV-Electrolyzer fuel cell

3. Results and discussion

The amount of hydrogen gas production at 24 V voltage and 3 M concentration obtained the discharge of hydrogen gas by 2.644 ml/s. Then the production of hydrogen gas rises steadily until it reaches the highest of 6.015 ml/s at 30 V voltage and 3 M concentration. So it can be obtained the best production value of hydrogen gas that is 6.015 ml/s at 30 V voltage and 3 M concentration. But due to the voltage constraints in PV only 24 V. Then the concentration we chose for the testing of the PV-Electrolyzer-Fuel Cell system is 3 M with the best hydrogen gas production of 2.6443 ml/s at 24 V that showed in Fig. 3.

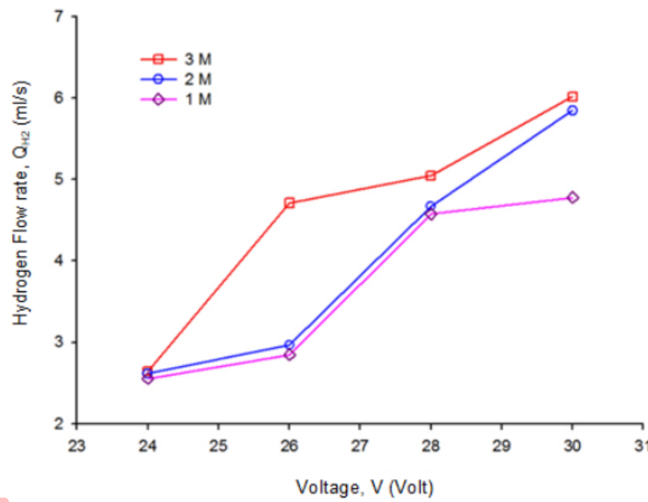

Figure 3. The relationship between voltage and Hydrogen flow rate with solution concentration variation of KOH

In Fig. 4 showed that for all concentrations the increase in voltage will increase the amount of oxygen gas production, according to Law 1 Faraday which explained that the mass of substances produced on an electrode during the electrolysis process is directly proportional to the electrical charge used. Thus, it can be obtained the largest production value of oxygen gas is 3,667 ml/s at voltage 30 V and concentration of 3 M. But due to the voltage constraints on the photovoltaic only 24 V. Then the concentration we chose for the testing of photovoltaic-electrolyzer-fuel cell system is 3 M with the highest oxygen gas production discharge of 2,223 ml/s at voltage 24 V.

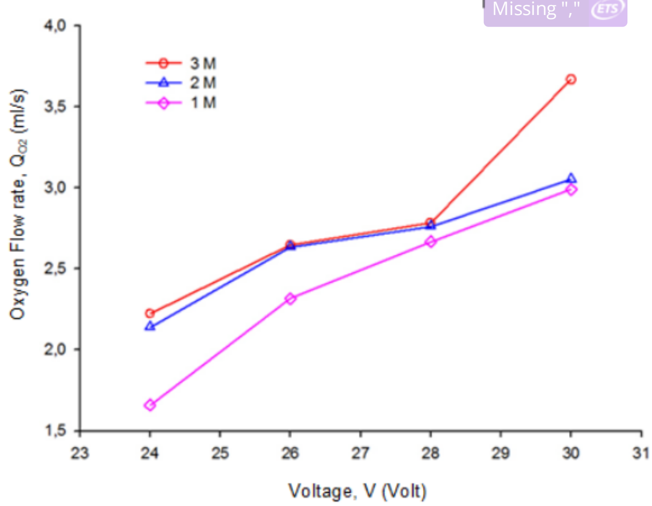

Figure 4. The relationship of oxidant flow rate and the voltage in KOH concentration variations

Increasing the current on the load will lower the voltage on the fuel cell, in Fig. 5. At the load of 5 current lights decrease followed by voltage, this is based on PEM fuel cell characterism. So at the

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concentration of 1 M obtained the highest current value of 0.76 A at voltage 2.6 V. The increased current on the load then the output power on the fuel cell is increasing. At the load of 5 current lights decreased followed by a decrease in output power, this is based on PEM fuel cell characterism. Thus, on the concentration chart 1 M obtained the highest output power of 1,976 W at current 0.76 A.

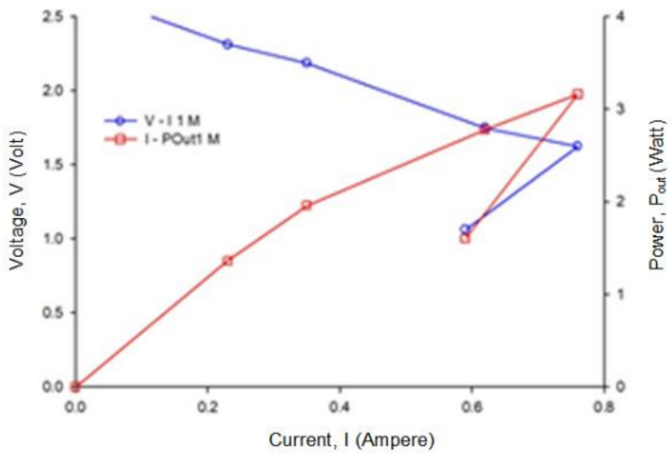

Figure 5. The relationship between cell output power, current, and voltage between electrolyzer and fuel cell at KOH 1 M concentration

At the concentration of KOH 2 M solution can be analyzed that the increased current on the load will lower the output voltage on the fuel cell. At the load of 5 current lights decrease followed by voltage, this is based on PEM fuel cell characterism. So in the concentration chart, 2 M obtained the highest current value of 0.89 A at voltage 2.2 V. Figure 6 below can be analyzed that the more current increases on the load then the output power on the fuel cell increases. At the load of 5 current lights decreased followed by a decrease in output power, this is based on the characterism of PEM fuel cell. Thus, the 2 M concentration chart obtained the highest output power of 1,976 W at the current 0.76 A.

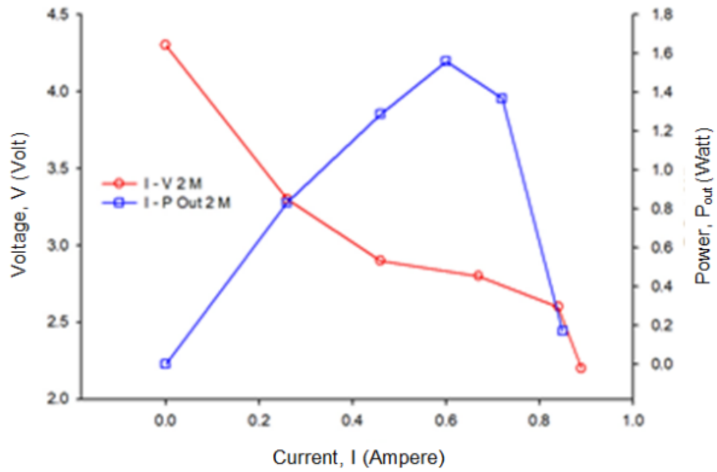

Figure 6. The relationship between output power, current, and voltage between electrolyzer and fuel cell at KOH 2 M concentration

Furthermore, in Fig. **7** shows the relationship between the current, voltage and output power of the PV-Electrolyzer-Fuel Cell system at a solution concentration of KOH 3 M can be analyzed that the increasing current at the load will lower the output voltage on the Fuel Cell. 2 M concentration with zero loads obtained voltage of 4.3 V, current 0 A. Then the load is adjusted until the voltage drops to 0.2 V until the current rises to 0.85 A.

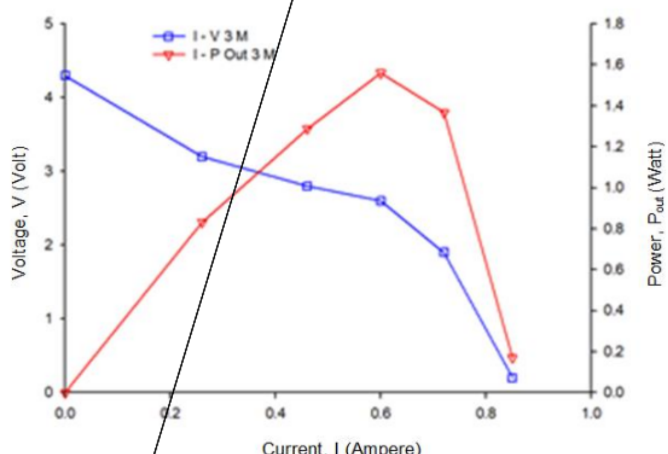

Figure 7. The relationship between current, voltage and output power of the PV-Electrolyzer-Fuel Cell the system at a solution concentration of KOH 3 M

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In Fig. 8 shows the relationship the output power and efficiency of the PV-Electrolyzer-Fuel Cell system in a variation of the solution concentrations of KOH can be analyzed that the increased load then the output power and system efficiency will be increased. Next at a concentration of 3 M with output power 0.858 W obtained an efficiency of 0.75%. Then the output power continues up to 2.184 W so that the efficiency rises to 1.84678%. Then efficiency dropped to 1.958% in output power 1.64815 W. So it can be obtained efficiency photovoltaic system, electrolyzer, and the fuel cell is the best 2.372% at 1 M concentration, voltage 2.6 V, current 0.76 A, output power 1.976 W.

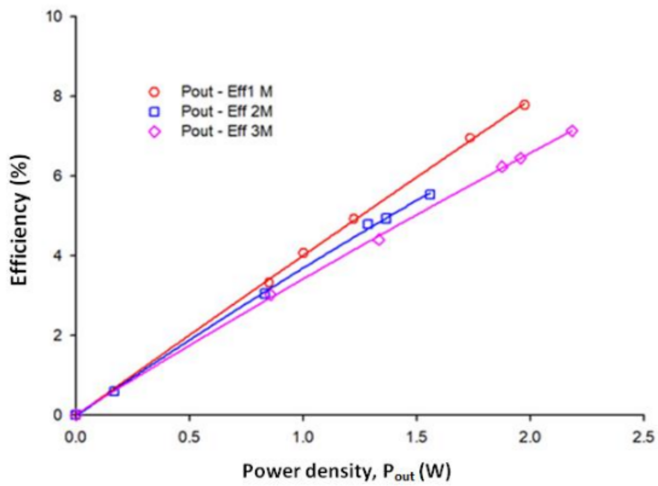

Figure 8. Output power and efficiency of the PV-Electrolyzer-Fuel Cell system in the solution concentration variation of KOH

4. Conclusion

This device is a technology approach using the small and large-scale PV-Electrolyzer-Fuel Cell to generate power as needed while raising the voltage is done with the addition of the cell stack, so it will increase the efficiency and power of fuel cell generated. Design and application of PV-Electrolyzer-Fuel Cell will increase the efficiency and power of Fuel cell as needed and this product can be downstream to the community in remote areas that have not installed the power grid

This study resulted in the following conclusions:

1. Testing Electrolyzer obtained the value of the flow rate of hydrogen gas flows and the best O_2 gas with a variation of voltage obtained at the concentration of Solution KOH 3 M. Photovoltaic testing obtained the best efficiency value at 14.00 WIB that is at 7.328% with an output power of 82.25 Watt. While in the testing of PV-Electrolyzer-Fuel Cell obtained the highest efficiency at a solution concentration of 1 M is 2.372% with output power 1.976 Watt.
2. In the test of PV-Electrolyzer-Fuel Cell based on the variation of the concentration of the KOH solution obtained the same output power, so that the efficiency gained will be small when the concentration is getting bigger.

Acknowledgment
The authors gratefully acknowledge the financial support provided by the Ministry of Research Technology and Higher Education of Indonesia under the contract of 152/SP2H/AMD/LT/DRPM/2020 and P3M Polines with contract number of 25/E1/KPT/2020.

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