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Proceeding Paper

Dynamic Model to Expand Energy Storage in Form of Battery and Hydrogen Production Using Solar Powered Water Electrolysis for Off Grid Communities †

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Abstract: In this model, we used a 50 WP photovoltaic panel to produce electrical energy. This electricity production was used directly and stored in a battery. In this design, we coupled batteries and hydrogen as a means of storing energy. In case of overcharging the battery, it will be attached with water electrolysis to convert the excess amount of chemical energy of the battery into hydrogen energy storage. Hydrogen will be stored as a compacted gas and in chemical storage. We used PEM (proton exchange membrane) electrolysis technologies to breakdown water molecules into hydrogen and oxygen, which were then stored in the designed tanks. Different supply voltages were used in our practical readings, with an average gaining of 22.8 mL/min on a voltage supply of 2. While using Ansys simulation software, we extrapolated hydrogen production until reaching 300 mL/min on 12 V of supply (which represents 220% higher production). By using the second phase of this model, hydrogen energy was converted back into electrical energy with the help of a PEM (proton exchange membrane) fuel cell when needed. This model explores the feasibility of energy storage in the form of hydrogen and chemical energy for off-grid communities and remote areas comprising batteries, water electrolysis, and fuel cells. The main purpose of hydrogen storage in this system is to store and handle the extra energy of system produced through PV panel and utilize it for any desired requirements.

Keywords: PV panel; off grid communities; hydrogen energy storage; PEM fuel cell

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1. Introduction

As of now, researchers and government organizations are focusing on use of renewable energy resources around the world due to high energy consumption and changes in the climate caused by conventional energy sources. In this model, our aim was basically to convert and store electricity in the form of hydrogen. In the globe, hydrogen is considered to be the most significant source of renewable energy since it is non-pollutant, clean, safe, and environmentally friendly. Considering the developing demand of energy in Pakistan, the effective use and advancement of sustainable power sources has become a significant problem in the country [1]. Rising anti-ecological damaging activity has contributed to a massive increase in worldwide energy utilization. At present, production of energy by fossil fuels has resulted in ecological damaging activities and the creation of toxic chemicals that has led to climate change and environmental degradation. Hydrogen will be the main energy source for the worldwide economy later on. Experts, organizations, and countries are starting to think about it as a long-term alternative best for remote areas. This study explores the feasibility of energy storage in the form of hydrogen and chemical energy off-grid energy system comprising water electrolysis and a fuel cell. In this system, PV panels are used to produce electrical energy. This electricity production is called direct current (DC) and can be used immediately or stored in a battery. In PV systems, batteries are used for storage, but they need a lot of space to extend the storage [2]. However, other storage methods may also be used in various kinds of structures or applications. In this system, we will use combined batteries and hydrogen as mean to store energy and determine which is the most effective configuration for remote areas. In this system, we analyze different types of batteries and fuel cell membrane materials for increasing the storage of hydrogen production [3].

2. Methodology

For this research, we used a 50 WP polycrystalline solar panel with the following dimensions: 655 × 670 × 25 mm. The project design mainly consists of a PV panel, lithium-ion battery, water electrolyzer, hydrogen storage medium, and fuel cell. PV panel attached with battery for storing electric power in form of chemical energy. Similarly, the PV panel has a direct connection with the electrical load through the data bus. Firstly, the PV panel provides electricity to the required electrical load and then in case of excess amount of electricity it stores this electricity in the battery [4]. Secondly, in case of overcharging the battery, it uses water electrolysis to convert excess amount of chemical energy of battery into hydrogen energy and stores this in the designed hydrogen storage (i.e., hydrogen stored as compacted gas and chemical storage). Hydrogen energy converted back into electrical energy with the help of fuel cell. The main purpose of hydrogen storage is to store the extra energy of system produced through the solar panel and utilize it for the desired requirements [5]. Following flow chart is shown the whole process of our designed setup in Figure 1.

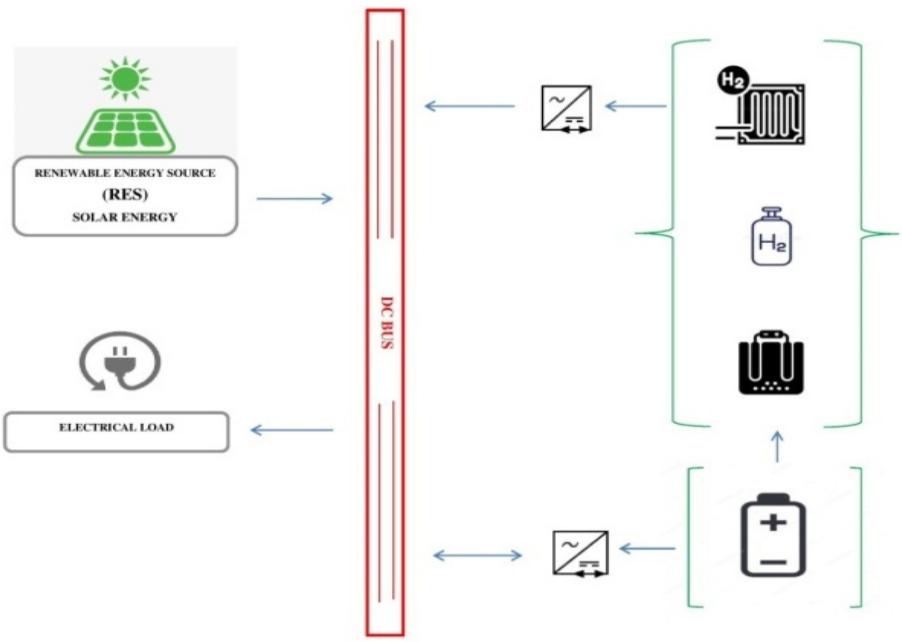

Figure 1. Flow chart of designed setup.

3. Results and Discussion

The first reading of the experiment at a voltage of 1.6 resulted in a bigger number as compared to the rest of readings. The average production at 1.6 volts is still 9 mL of hydrogen (although it was 13 mL in 1st reading). In the next phase, it expresses a moderate change in production of hydrogen, which is 9.2 mL on 1.7 voltages. While switching to 1.8 V, it shows a huge inclination in output. At 1.8 V its average output was 14.8 mL, and graphical data shows a hypotenuse line or curve with that result. It was five times higher than the previous two experimental results. By reaching a 1.9 V input, it presents a continuous improvement in output result that is 19.6 mL and stays tuned on 2.0 V by giving 24.4 mL. In a nutshell, the electrolyzer breaks down the water molecules at a fast pace by slightly increasing the input voltages. The hydrogen production result also shows noticeable inclination in following Table 1 and graphical representation also shown in Figure 2.

Table 1. Production of hydrogen from 1.6 V to 2.0 V.

Sr No.	Particulars	Practical Readings				
		1.6 V	**1.7 V**	**1.8 V**	**1.9 V**	**2.0 V**
1st Reading	$\mathbf{H_2}$/(mL)	13	12	18	24	24
2nd Reading	$\mathbf{H_2}$/(mL)	8	10	14	18	27
3rd Reading	$\mathbf{H_2}$/(mL)	8	8	14	20	24
4th Reading	$\mathbf{H_2}$/(mL)	8	8	14	18	25
5th Reading	$\mathbf{H_2}$/(mL)	8	8	14	18	23
Average Reading	$\mathbf{H_2}$/(mL)	9	9.2	14.8	19.6	24.4

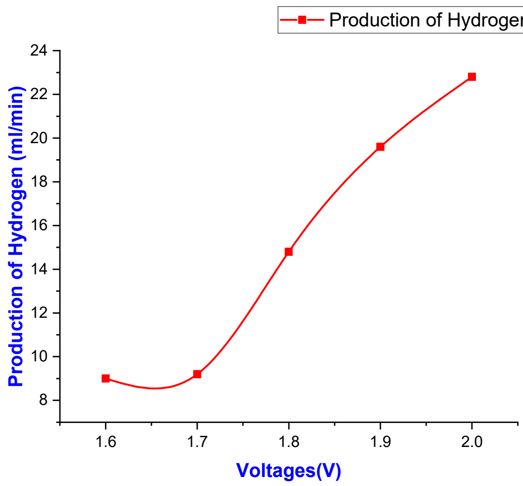

Figure 2. Graph of production of hydrogen.

After converting electrical energy into gasoline, a fuel cell is needed to convert it back into electrical energy whenever required. However, this whole process drained a major amount of energy and only delivered 10% of the input energy. This major loss can only be recovered by increasing input voltage as represented in the graphical chart shown below. By extrapolating the input voltage until 12 or 14 volts it shows a linear line of production rate and input. At 1.6 V it showed 9 mL hydrogen production while at 12 V it shows 300+ mL hydrogen production (which is 220% higher production than 2 V). Following Figure 3 shows the graphically representation of hydrogen extrapolation.

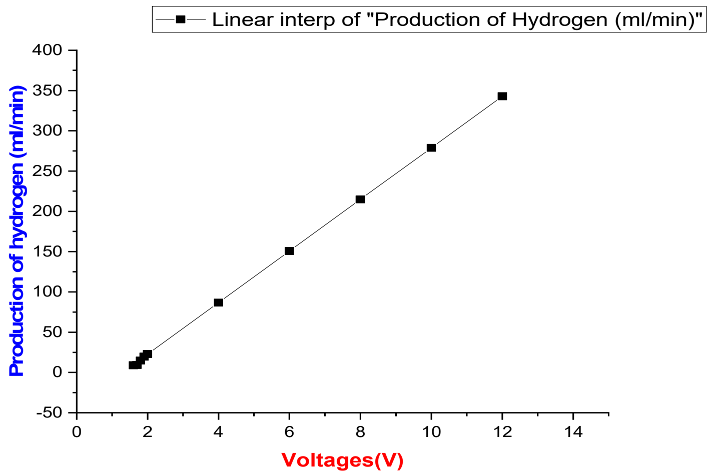

Figure 3. Graph of extrapolate production of hydrogen.

4. Conclusions

In the present research work, a PV based off-grid energy system using electrochemical batteries for short term energy storage and a hydrogen storage system for seasonal storage was investigated. According to this research, we increased the overall storage capacity and the efficiency of the system in the form of a hydrogen tank. The hydrogen tank volume is 34 m^3 and can store up to 230 L of hydrogen that can be used for variety of purposes. In this research, we focused on regenerating electricity by using fuel cells. By using this model, we can provide 40AH (12V DC) backup to the system. By using hydrogen stored in a hydrogen tank, we can regenerate electricity with the help of fuel cells and enhance the overall efficiency of the system in the absence of sunlight or another primary source of electricity. This research is very beneficial for off grid communities, remote areas, and especially in space. However, the other goals of this research to increase the storage of solar energy and its utilization in different resources for multiple purposes. Hydrogen can be used for burning and combustion engines and oxygen can also be used for medical and a variety of other purposes.

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Conflicts of Interest: The authors declare no conflict of interest.

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