

Dynamic model to expand energy storage in form of battery and hydrogen production using solar powered water electrolysis for off grid communities

DOI : 10.36909/jer.ICEPE.19565

Ali Mushtaq, Tajjamal Hussain, Ghulam Abbas, Khurram Shahzad Ayub*, M. Salman Haider*

Department of Chemical Engineering, HH Campus, University of Gujrat, Pakistan.

School of Resources and Environmental Engineering, East China University of Science and Technology, Shanghai 200237, China.

* Corresponding Author: enr.ghulamabbas@uog.edu.pk

ABSTRACT

In this version, we used a 50WP PV panel to generate electricity, according to this strength output is getting used directly and it's far being gathered in a rechargeable battery. In this layout we connected batteries and storage of hydrogen to keep strength for the purpose of storing energy. If the rechargeable battery is overcharging, it'll be linked to the water electrolysis so that a big quantity of chemical power of the battery may be transformed into hydrogen and stored into hydrogen storage. Hydrogen may be stored as compacted gas and chemical storage. In this model we used proton exchange membrane electrolysis technology to break up water into hydrogen and oxygen after which stored in our designed tanks. Variation of voltages are used in our practical's, we get mean value of hydrogen production is 22.8 ml/min on 2 supply voltage. Via using simulation software (Ansys), extrapolates the production of hydrogen 300ml/min on 12v supply that is 220% higher. Moreover, using second section of the designed, hydrogen converted again into electrical energy by using proton exchange membrane fuel cell. In this designed including batteries, water electrolysis and fuel cells, explores the feasibility of storing energy in the

form of hydrogen and chemical energy for off grid areas and remote communities. The primary goal of hydrogen storage in this system is to store and manage the excess energy of the system generated by using PV panel and use it for the desired want.

Keywords: Hydrogen Energy Storage; Off Grid; Proton Exchange Membrane Fuel Cell; PV Panel

INTRODUCTION

Professional and official corporations are emphasizing on utilization of energy resources in the whole world because of high electricity usage and climate change as a result of the conventional electrical sources. In this designed basically our goal to conversion and saving energy in the form of hydrogen. Inside the globe, hydrogen is considered to be the most suitable and attractive source of renewable energy as its non-pollutant, clean, safe and environmental friendly. Considering the growing call of energy in Pakistan the effective use and upgrade of sustainable power sources has become a rising problem in the country. In this model firstly we will use solar panel for production of electricity because Pakistan is among those countries where sun light warms the surface consistently around the year and therefore has a high and solid potential for solar power generation. Moreover, Most critical growing trend over climate change is the reality that solar electricity production provides a clean and green alternative to electricity from fossil fuels and many old methods without any type of pollution for example no air, water and other environmental pollution. Furthermore there is no global warming pollution or risks of electricity charges spikes and no any type of critical human health threats.

In this model, PV panel are used to generate electricity, this power production is called direct current and stored in a battery. In photovoltaic systems, storage is used to maximize the amount of time the PV system can be used to power. In PV systems, batteries are used for storing energy, but they need extra space to extend the storage but other storage methods also

be used in different kinds of applications. As an instance, in this model we convert excess amount of electric power that saved in batteries into hydrogen with the aid of fuel cell. In this designed we use combined batteries and hydrogen as mean to store energy, and analyzed out which is the most effective combination for remote areas.

TERATURE REVIEW

Due to increase in human population and environmental issues, use of renewable energy has increased. Hydrogen production by solar powered water electrolysis has attracted many researchers around the globe being the most significant type of renewable energy sources.

There are following two main approaches of my proposed research:

1-Production of electricity through (RES) solar panel

2-Storage of electricalenergy in the form of chemical energy like battries and hydrogen storage

1- Production of electricity through (RES) solar panel

Solar electricity is transformation of energy from daylight into electricity, from using photovoltaic and also utilizing concentrated solar power. CSP framework utilizes lenses and solar tracking systems to focus enormous daylight into a small beam. PV panel exchange light into electric current utilizing PV impact (Bagheri, Shirzadi et al. 2018). Solar PV is cheapest way to the production of electricity in most of countries. In particular, utility-scale Photovoltaic has broken many records of the lowest power purchasing commitments in the world. In the last ten years, solar Photovoltaic module prices have decreased by more than 95 percent and device prices have decreased by almost 85 percent in real terms and continue to decrease according to a steady and upward learning pace of 38.9 percent for Photovoltaic modules from 2006 to 2018, Due to market growth of 47 percent compound annual growth of cumulative Photovoltaic capacity in the same period, this has led to a very quick cost decrease (Ehteshami and Chan 2014). In 2017, 1.7% of the world's

electricity was generated by solar wind, an increase of 35% over the previous year. The uninterrupted cost of solar power on a utility scale is approximately 36 / MW after October 2020 (Ehteshami and Chan 2014). Many industrialized countries have installed solar energy in their grids, while a growing figure of under developing countries have change their focus to solar to minimize their dependency on high price imported fuels. In this solar plants use one of two technologies:

- Photovoltaic (PV) systems use solar panels, either on rooftops or on ground solar farms that convert sunlight directly into electricity.
- Concentrated Solar powered plants use solar energy to generate steam which is converted into electricity by turbines (Ehteshami and Chan 2014).

History: (Mid-1990s to early 2010)

Private as well as domestic and industrial developments such as business housetop solar and PV supply problems with oil/gas, unnatural weather shifts, and development of PV financial situations belong to energy technologies. The reception of feed-in tariffs in the mid-2000s, a strategy mechanism that provides grid needs for renewables and characterizes fixed electricity production costs, prompted a substantial level of investment protection and the take-off of a number of PV arrangements in the countries of European union.

At present

The overall development of sun-oriented PV has been driven by European deployment for quite a while, particularly China, Japan and to increasing nations around the world. In 2014, Tokelau turned into the primary nation to be fueled totally from PV panels, with a 1.5 MW framework utilizing batteries for evening energy. Overall development of photovoltaic has found the middle value 45% yearly between 2002 to 2013. The biggest producers are

situated in China. CSP began to develop quickly, expanding its ability almost ten times between 2006 and 2015.

2- Storage of electricity in the form of batteries and hydrogen

Batteries

A few sorts of batteries are utilized in huge area for energy storage. All contains on electrochemical cells; however multiple cell categories are appropriate for all purposes. These sections, shown the properties of different kinds of batteries utilize enormous level for energy saving, for example the nickel cadmium, lead acid, lithium ion, sodium sulfur and flow batteries (Barzola-Monteses and Espinoza-Andaluz 2019).

Lead acid batteries

Invented in 1869, lead acid batteries are the former rechargeable battery class and a liquid electrolyte was used. These batteries' invention is easy in nature and cost is low; however, these batteries are delayed to energy, cannot be fully de-energized and have a minimum number of cycles of charge/(Ferreira, Garde et al. 2013). In renewable energy source applications multiple deep cycles lead acid batteries, which deliver a constant current for long term. For example, deep-cycle lead-acid batteries are manufactured in PV systems by closed backup and peak shifting (Parker 2001).

Lithium ion batteries

Lithium-ion batteries have been a major penetration of consumer electronics markets and are transforming hybrid and electric vehicle applications. Growth of the industry in the automotive and electronics markets can create the potential for aggregating and consolidating economies on a large scale, they will probably find their way into grid storage applications as well. Manufacturers are looking to bring down maintenance and operating expense, convey good productivity, and guarantee that enormous banks of batteries can be controlled. Moving

forward with increasing charging conditions will increase the number of in-grid applications for this battery framework (Mortalò, Santoru et al. 2019).

Nickel–cadmium batteries

A positive electrode made of nickel oxyhydroxide and a negative electrode consisting metallic cadmium make up a nickel-cadmium battery. These are divided by a divider made of nylon Aqueous is a potassium hydroxide electrolyte, which does not change much during activity, however, oxygen can be produced at the positive electrode during charging, and hydrogen can be produced at the negative electrode. As a result, some extraction and watering is required, but lead acid is much less than a battery (Bruce, Scrosati et al. 2008).

Sodium sulfur batteries

Sodium sulfur batteries that use metallic sodium and provide attractive solutions for many large-scale energy storage applications for electrical performance. Sodium sulfur battery is a sodium and sulfur type molten metal battery. This form of battery has a high energy capacity, high charge / discharge production capacity (76-85%), and it is the highest of the products released by suitable chemicals at 310-360 °C operating temperature and sodium polysulfide. Due to the nature of the corrosion. For example, these cells are generally ideal for large, non-portable needs (Yuan, Zhang et al. 2014).

Flow batteries

Flow battery consisting electrolyte that dissolved electro-active species is transferred directly to electricity through an electrochemical cell that transmits chemical energy. Extra electrolytes are placed away externally, normally in tanks, and are generally pumped through the reactor cell, despite the fact that there is also gravity feeding systems available. By removing the electrolyte fluid and at the same time recycling the spent material that would be

reenergized in a separate phase, flow batteries can be rapidly reenergized (Yamamura, Wu et al. 2011).

Hydrogen storage

Hydrogen is produced from different renewable energy resources that have the potential to become the main fuel of 21st century. Hydrogen makes it possible to decrease emissions altogether in the entire fuel cycle. In hydrogen storage systems less hazard, economical and practical are the most important thing is to enable large amounts of H_2 as an energy carrier. In present era, H_2 stored as a compressed gas. Mostly compressed hydrogen tanks have smaller diameter and enable with optimized packaging. Pressure vessels are divided into four types, types I, II, III and IV. In our model we simulate on Ansys software type IV vessel due to some technical reasons. Hydrogen storage design having factors:

- Gravimetric efficiency
- Volumetric efficiency
- Compatibility with hydrogen
- Less resistance
- Compatibility with temperature extremes
- Compatibility with fast filling and charging
- Resistance to external corrosion

In this design we ensure multiple levels of safety protections and overfilling issues that accomplished via safety algorithms and pressure relief valves or devices at the fuel tank. Some safety considerations are deployed in this design during simulation due to high risk of leakage, high stresses related to high service pressure, high temperature during fast filling and hydrogen embrittlement. Carbon and steel are the most common materials for the construction

of the hydrogen tank but we use carbon-fiber material in our simulation due to some following properties of materials. Carbon-fiber is engineering material that has desiring characteristics such as less weight, great strength, very high stiffness, long fatigue life cycle, and high resistivity against huge number of chemicals.

Hydrogen can use as energy carrier and storage that can be produced through splitting of water, stored separately in storage tank and with the assistant of fuel cell can be changed back to power. Hydrogen is a sustainable and renewable energy source (RES) and harmless eco system energy carrier having the capacity to replace fossil fuels in worldwide hydrogen has insignificant to unimportant negative impacts on the climate because of clean, green and natural friendly fuel. Hydrogen comprising 74.5 % of all matter by mass and 90.5% while thinking about quantity of molecules so it's the lightest and most bountiful component altogether over the world. Hydrogen is the component of water that covers 74.5% on the Earth land and is in like manner typically found in different carbon based particles (Mariolakos, Kranioti et al. 2007).

Hydrogen has the ability to be a strong energy carrier, as hydrogen can be quickly replaced by thermal, mechanical and electrical energy. Presently, Hydrogen is being utilized in lot of the ease adjustment modifications internal combustion engines. Hydrogen is a cleaner fuel that uses hydrogen more efficiently than petrochemicals, so cars use hydrogen as an energy source because it has very low emissions levels that are environmentally harmful. In addition, hydrogen has the lowest viscosity of all liquids, resulting in less friction; otherwise, in any case, heat loss contributes to the loss of general energy. Similarly, hydrogen is a better fuel for domestic and industrial heating purposes. It has demonstrated its ability to provide better energy sources within aviation firms, with the combustion of H_2 and O_2 emitting the highest energy per fuel weight (Gracia, Casero et al. 2018).

Hydrogen, on the other hand, has an advantage as an energy carrier that, when compared with batteries, improves the effectiveness of the hydrogen storage framework. For example, deep de-energized metal hydrides do not have horrible effects, whereas deep de-energized batteries are known to adversely affect battery performance. Hydrogen storage medium also has a long lifespan (Zheng, Liu et al. 2012).

Among the all energy carrier's hydrogen is comparatively a light fuel source that can be put away effectively and hold the most worthy energy per mass. Currently, storage choices for hydrogen comprise of cryogenically freezing, compacted gas and chemical storage, like chemical hydrides, metal hydrides or sorbents. Freezing hydrogen is more energy saving method than compacted hydrogen and packed state requires extra storage space (Zhang, Jia et al. 2015).

METHODOLOGY

In this research we used 50WP solar panel having dimensions of 655×670×25mm. The design consists of photovoltaic panel, battery, electrolyzer, hydrogen storage and fuel cell. PV panel connected with rechargeable battery for saving power as a chemical energy. Photovoltaic panel have a connection with electrical load via data bus. In first section, Photovoltaic panel provide power to electrical appliances and afterwards in case of extra amount of energy it stored in connected rechargeable battery. In second section, if battery is overcharged then it attached with the electrolysis to convert extra chemical energy of battery into hydrogen for seasonal storage and its production approximately 0.5kg per day. Hydrogen energy converted back into electrical energy by using fuel cell. Aim of hydrogen storage is saving the extra amount of energy produced via solar panel and utilizes it according to requirement.

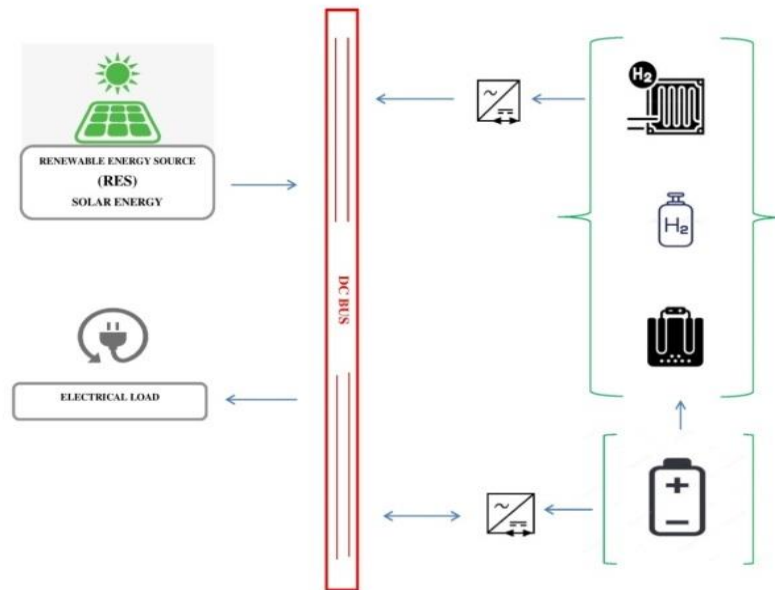


Figure 1. Flow Chart of Designed Setup

As shown in above figure renewable energy source that is solar connected to DC bus. Dc bus deliver electrical energy to desired load and extra energy delivered to the batteries where electrical energy converted into chemical energy. Batteries used to deliver energy back to data bus for load requirement and for storing energy into another form by using electrolyzer and water. Extra energy of batteries converted into hydrogen and oxygen and later on when we need, converted again in electrical energy via fuel cell. The detailed procedure and capacity of components is given below. We used a 50w solar plate and connect it with batteries and then pass its connection to electrolyzer. For production of hydrogen and oxygen, we use H-Tec module that is consist of 1 electrolyzer connected with 2 vertical water tanks holding oxygen and hydrogen on the top of tank apparently and then connected hydrogen and oxygen storage cylinders as well. Electrolyzer breaks water molecules into oxygen and hydrogen and pass it to storage cylinders. Production of hydrogen is 2 times greater than oxygen as it also represented in water formula. Variation of input voltage to electrolyzer also impacts the

production of hydrogen and oxygen. In this experiment we used solar panel, batteries, H-Tec module, water beakers and storage cylinders. There are two methods to calculate the production rate of hydrogen and oxygen. 1st one is by using water tank gauge we can calculate hydrogen and oxygen production by considering change in water level or change in volume but this is least efficient method. 2nd one is by using water beakers and tubes that is most efficient method neglecting pressure factor. In this method we took oxygen and hydrogen output through rubber vanes and connect it with the tubes. Water filled Tubes were placed downward in open mouth water filled beakers. When gas flow started towards test tube it made some pressure in test tube head and then started uplifting it. Due to gas pressure test tube uplifted and start releasing water from it and store gas in it. This method was only used to justify the production rate of hydrogen and oxygen.

RESULTS AND DISCUSSIONS

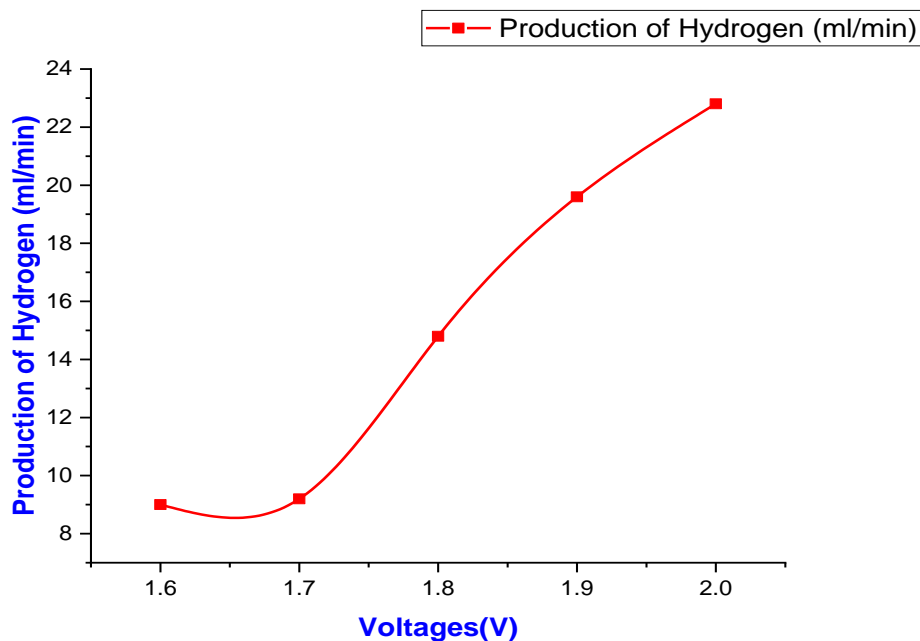
The results shows that voltage value has a direct relation with output of hydrogen and oxygen. As table data represents five experiments readings which clearly show the inclination in hydrogen production with slightly change in voltage.

Table of Hydrogen Production

	(ml)	Practical Readings(v)				
		1.6	1.7	1.8	1.9	2.0
First Reading	Hydrogen	13	12	18	24	24
Second Reading	Hydrogen	8	10	14	18	27
Third Reading	Hydrogen	8	8	14	20	24
Fourth Reading	Hydrogen	8	8	14	18	25
Fifth Reading	Hydrogen	8	8	14	18	23
Average	Hydrogen	9	9.2	14.8	19.6	24.4

Table 1. Values the production of hydrogen from 1.6v to 2.0v

Here we also attached a graphical representation of data which make it crystal clear and understandable from every aspect (figure 2).

**Figure 2.** Graph shows Values the production of hydrogen from 1.6v to 2.0v

1st reading of experiment at 1.6 voltage result gave a big figure as compare to the other readings. The average production at 1.6v embarks 9ml production of hydrogen although it becomes 13ml in first reading. In next segment it shows slight changing in production of hydrogen that is 9.2ml on 1.7v. While switching to 1.8v it shows a massive inclination. At 1.8v its mean output becomes 14.8ml and graphically data represent a hypotenuse line on that result. It turned 5 times than the previous 2 experiments result. As achieving on 1.9v input it presents improvement continuously in output result that is 19.6ml and stays tuned on 2.0v by giving 24.4ml. To conclude, electrolyzer wreck down the water molecules on rapid pace through barely increasing the input voltages and hydrogen production result is likewise indicates major inclination.

Table of Oxygen Production

Sr. No.	(ml)	Practical Readings(v)				
		1.6	1.7	1.8	1.9	12.0
First Reading	Oxygen	6	6	9	12	12
Second Reading	Oxygen	4.5	5	7	10	11
Third Reading	Oxygen	4.5	4	7	9	10
Fourth Reading	Oxygen	4.5	4	7	9	11
Fifth Reading	Oxygen	4.5	4	7	10	11
Average	Oxygen	4.7	4.6	7.4	10	11.2

Table 2. Values the production of oxygen from 1.6v to 2.0v

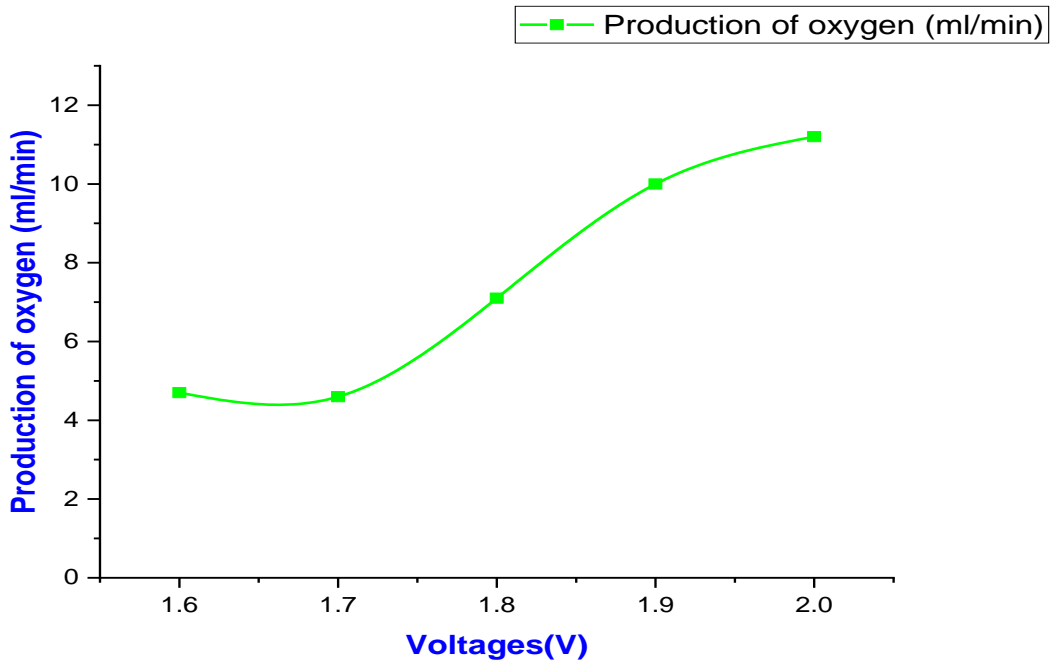


Figure 3. graph shows the production of oxygen from 1.6v to 2.0v

Starting the production of oxygen at 1.6 voltage results a small amount like 4.5ml that is the half of hydrogen production at 1.6v. As its formula H_2O presents its ratio that is 1:2. The average production at 1.6 volt still holds 4.7ml oxygen as output although it was 6ml in 1st reading. In next section it expresses downward flow in production of oxygen that is 4.6ml on 1.7v but it's not a different behavior as compare to hydrogen production. While switching to 1.8v it shows a high inclination in output. At 1.8v its average output was 7.4ml and graphical data represent a hypotenuse line or curve on that result and it was also exactly half of the hydrogen production at same input volts. It was almost double than the previous 2 experiments result. As reaching on 1.9v input it presents improvement continuously in output result that is 10ml and stays tuned on 2.0v by giving 11.2ml. As a whole production rate of oxygen was up and down on starting but by increasing continuous improvement. Oxygen production was almost half than the hydrogen production result. It also prove that water electrolyzer have direct relation with input voltage and output. By increasing input voltage production curve express a positive response.

Extrapolate Values of Production

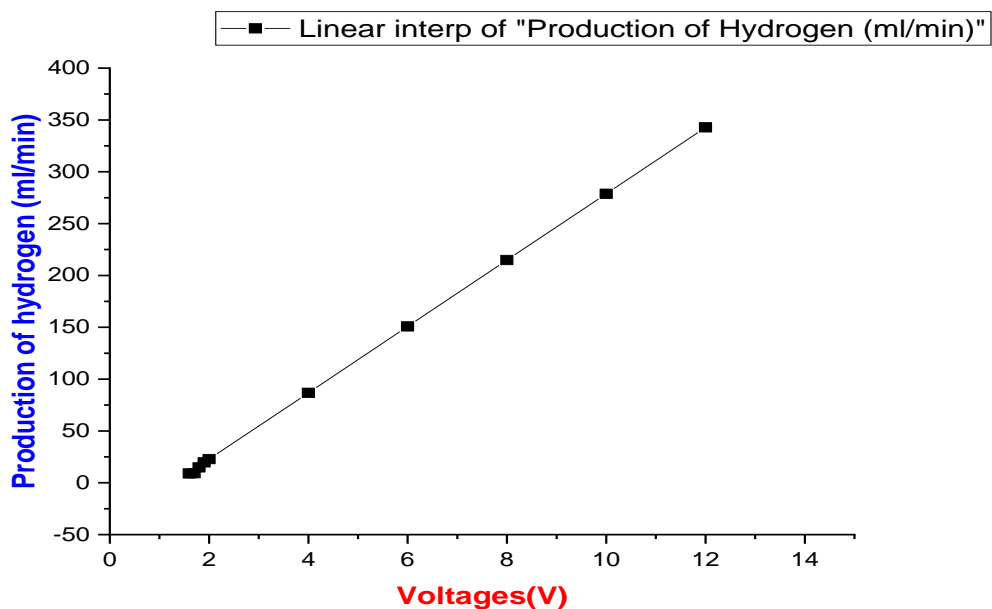


Figure 4. Graph shows the extrapolate production of hydrogen from 1.6v to 12v

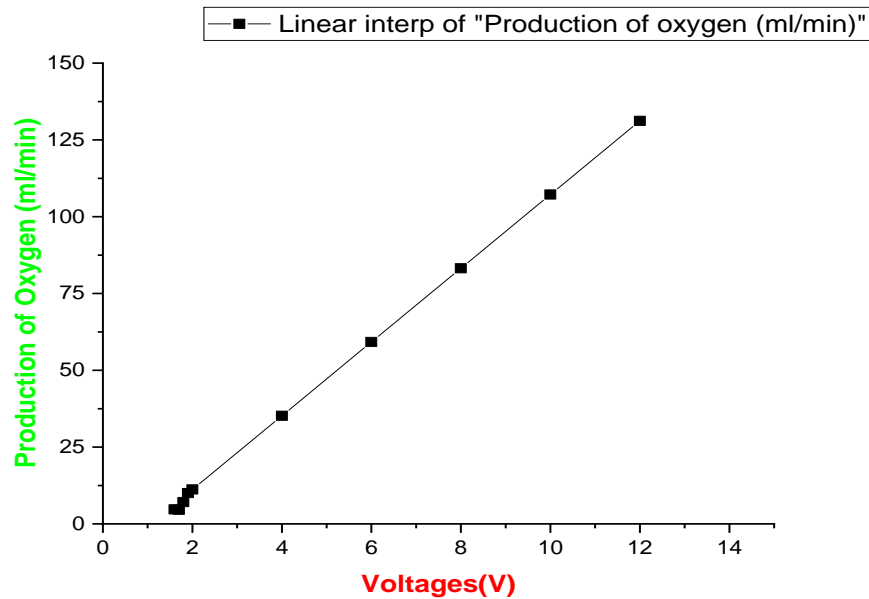


Figure 5. Graph shows the extrapolate production of oxygen from 1.6v to 12v

After converting electric energy into gasoline fuel cell is needed to transform it again into electric energy each time it desired but this process drained huge amount of electricity and supply 10% of input energy. This most important loss can best be get better via increasing enter voltage as represented in chart proven beneath, through extrapolating input voltage until 12v or 14v it indicates linear line of manufacturing rate and enter. On 1.6v it presented 9ml hydrogen generation while on 12v it presents 300+ ml hydrogen productions that is 200% higher production than 2v. Oxygen shows same like hydrogen production rate fluctuation but its production is half than the hydrogen that is reasonable due its water formula. Here we can say by increasing input voltage efficiency of electrolyzer and fuel cell can be increased apparently. Hydrogen can also be used for combustion purposes in vehicles which are more efficient method and environment friendly as compare to fuel combustion engines. Hydrogen can be used for multiple purposes like in rockets and fighter jets to boost speed and so on. Oxygen can be used for ventilator and other purposes too. It can also be used for burning purposes but its

main purposes are to provide inhaling power to the medical emergency patients. By using fuel cell hydrogen and oxygen can also be used in pilot projects or astronomy purposes too.

CONCLUSIONS

The achievement of renewable hydrogen production technology is a key initiate in sustainable human existence which uses renewable resources for energy production. However, renewable hydrogen generation technology has created significant advertising that has greatly increased its feasibility as an energy source. The method of generation, the need for renewable development remains hydrogen production technology that is more efficient to make economically competitive with existing hydrogen production techniques that use fossil fuels as a source of power for hydrogen production. In this work investigated a PV based off-grid energy system with batteries as short term storing energy and hydrogen storing system as seasonal storage. By utilizing this design overall we surge the storing capability and increase the efficiency of the model in the form of hydrogen storing tank because a lot of modern consumer devices base on virtually unlimited electricity.

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