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REVIEW ARTICLE

A SCHEMATIC DESIGN OF HHO CELL AS GREEN ENERGY STORAGE

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ABSTRACT

The continuous growth of population and energy-based industries have rapidly increased the demand on electricity and raised up the need for harmless and clean methods of electric energy generation and storage capacity. The world's governments found it is feasible to consider the renewable energy sources as another alternative to supply part of their electrical needs. Renewable energy will minimize the environmental pollution associated with non-green methods of electrical generation which occupy the largest percentage of generation. Thus, photovoltaic systems along with large batteries have been implemented to generate and store electricity. These batteries have bad influences on the environment because they contribute in the pollution when they are manufactured and when they are out of use (i.e. they need recycling treatment). In this paper, we propose a schematic design of optimized water analysis-based cells that efficiently generate and safely store the energy as Hydrogen-Hydrogen Oxygen (HHO) ions. HHO cells promote a green energy generation and storage since clean water is the chemicals that is release out of burning this fuel. The HHO ions will be used as a clean energy source that can run most energy consuming systems. Hence, HHO ion generation will be another alternative to improve the storage of renewable energy.

KEYWORDS

Clean Energy Storage, Current, Efficiency, Electrolysis, Energy, HHO Cells, Photovoltaic, Electricity Storage

1. INTRODUCTION

Recently, the enormous demand on the energy and its healthy alternatives have been recorded by almost every industrial and governmental sector as well as at personal level as worldwide serious issue. The annual world energy consumption increased rapidly for the last two decades which causes a rapid increase in environmental pollution thus push up the global warming to be a serious threat to our earth. Reducing the pollution associated with power generation and storing is getting more interest worldwide. Global warming is a major problem out of many other problems that the scientific community must find solution for it [1]. There should be efficient solutions that will reduce pollution to maintain safe environment for us and generations to come. One possible contemporary solution is the utilization of renewable energy which is considered as clean and relatively non-harmful source of energy. Thus, significant number of researches and experimental projects are being conducted around the world to optimize the exploitation of renewable energy. Hence, the energy storage mechanism occupied an explicit and substantial part of these contributions especially those utilizing batteries as energy reservoir. Large scale battery storage facilities associated with initial high cost to establish and to maintain considering the battery lifetime.

Generally, storing and using energy on demand via batteries create great amount of pollution in the form of waste of fabricating storage batteries and the wasted batteries itself. The process of using batteries as energy storage from fabrication to waste batteries are harmful to the environment since it contains hazard chemicals such as acids, Lead, lithium and others. For instance, Lead acid batteries consist of positive electrodes of lead dioxide and a negative electrodes of sponge lead, immersed in an aqueous sulfuric acid electrolyte. Indeed, these chemicals are not environment friendly. Pollution problem from batteries can be decreased by recycling -which is not cost-effective- or eliminating battery use by introducing new innovative green energy storage devices into the power system network [2].

Alternatively, Hydrogen-Hydrogen Oxygen (HHO) cells are newly developed innovative solution to store energy with no harm effects for any of the beings on earth. HHO generation cells are introduced to be a green alternative energy storage source because of its advantages, which have overcome the environment pollution and global worming issues. HHO generation cell is environmentally friendly because the hydrogen burns completely without creating pollutants, toxic fumes, or public nuisance. The HHO cells itself mainly in its simplest form stainless steel material that uses water (Saltwater increase the reaction more than the regular water) as an in product. The waste of the system is pure distilled water that can be used as drinking water after mixed with tap water. The output of HHO system is oxygen and hydrogen gases, where hydrogen gas can be stored and used efficiently as power source.

The use of Hydrogen gas as a power/supplementary source is not a new idea where it has been targeted by several researches and experiments to enhance, reduce and eliminate certain features of certain systems. For instance, in 1920s, a researcher has designed practical hydrogen-fueled engine and has converted over 1,000 engines to be hydrogen-fueled [3]. Also, since World War I, submarines were using hydrogen as a fuel and the major benefit comes from that was pure drinking water generation as a system waste. Airplane engineers considered powering their airship engines by hydrogen. Although, helium has been used to provide lift, hydrogen has been considered to supply additional buoyancy if it stored in a light container at low pressure [4]. Moreover, two General Motors engineers, have investigated the hydrogen-supplemented fuel effects on emission control with lean operation [5]. The investigation results have demonstrated that a small addition of hydrogen to the fuel, very low oxides of nitrogen (NOx) and CO emissions were achieved for hydrogen-isooctane mixtures leaner than equivalence ratio of 0.55 and there was significant thermal efficiency improvement yields from the extension further than isooctane lean limit operation. Similarly, a scholar has converted an engine

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of pickup truck to be powered by compressed hydrogen known as the American Hydrogen [6].

Moreover, a previous researcher has worked on enhancing combustion in the internal composition engine (ICE) via the electrolysis [7]. The production of hydrogen and oxygen have enhanced the combustion at low engine loads for all types of engines. While, the research group of transport technology at University of Gent has specialized in alternative fuels for around the past 14 years such as hydrogen, natural gas, liquid petroleum gas (LPG) and hythane-a combination of hydrogen and methane [8]. Thus, they have converted a Valmet 420D engine from diesel engine with direct injection, to a spark-ignition engine using hydrogen. On the other hand, a recent scholar has experimentally studied the improvement of fuel economy by hydrogen generator kit which can be installed on various engines of different vehicles [9]. Peavey Michael Anthony has designed and developed fuel induction systems to provide one intake path for hydrogen and one for air [10]. Saravanan et al. have experimentally tested the hydrogen-enriched air induction of a diesel engine system [11]. The test results achieved a 27.9% of efficiency exceeding the full load range with 30% hydrogen enrichment. In addition, it has been observed that the Specific fuel consumption (SFC) have decreased along the increase of hydrogen percentage over the entire range of operation. Furthermore, Ji and Wang have experimentally investigated the combustion and emissions performance of a hybrid hydrogen–gasoline engine [12]. They have shown that flammability and fast burning velocity of hydrogen have contributed in the reduction of CO and HC emissions at idle and lean conditions.

One more work was performed by C. H. Frazer who has invented the Hydrogen Booster which used to increase the efficiency of internal composition engine [13]. Stanly Meyer has built a water-fueled vehicle [14]. The vehicle is a dune buggy which runs by water using electrolysis board. It can run around 161 kilometers per gallon of water. Stanly has estimated that only 83 liters of water were required to travel from Los Angeles to New York [15]. Recently, several other important works have been conducted in [16-19].

Finally, in this paper, we are proposing a schematic design for three different alternatives of HHO cells (Square, Cylindrical or Spiral) trying to increase the output of gas while decreasing the input of current which make some designs are more effective than others. All plates were made from stainless steel-316 and uses regular rubber O-rings to separate them with reduced amount of input current and they were designed as wet cells in which plates are submerged in water. Also, for every single design, the chemical and electrical properties are considered to obtain the relations that represent the behavior of the design. Moreover, different types of water such as distilled water, tap water and saltwater is used to observe the best responses of the electrolysis and different methods of tuning the electrical input were applied to optimize the hydrogen emission. Finally, experimental results are reported for purpose of benchmarking of the three designs to determine which design is more efficient in terms of supplied power and amount of Hydrogen produced.

2. HYDROGEN-HYDROGEN OXYGEN (HHO) CELLS

Hydrogen-Hydrogen Oxygen (HHO) cells [3] are newly developed innovative solution to store energy with no harm effects for any of the beings on earth. HHO generation cells are introduced to be a green alternative energy storage source because of its advantages, which have overcome the environment pollution and global worming issues. HHO generation cell is environmentally friendly because the hydrogen burns completely without creating pollutants, toxic fumes, or public nuisance. Table 1 shows a comparison between HHO cell and battery from different aspects. In terms of availability, battery in the market is more available than the HHO cell due to the common think that the battery is the only energy storage element introduced to the world. Another aspect is the durability of the system; HHO cell is more durable because it constructed from special type of stainless steel (Type 304) that can last for more than twenty years without rust while the batteries approximately last for 2-5 years depending on its fabrication material before they become decompose and need for recycling [20].

Table 1: Comparison between HHO cell and battery from different aspects.

	HHO cell	Battery
Availability	Limited, in research phase	Available
Durability	Long time > 20 years	Usually 2-5 years
Component	Stainless steel	Chemicalsubstancei.e.Lead,sulfuricacid,lithium…etc.
Environmental impact	No bad impact	Cause pollution, Global warming
Cost	Lessexpensiveforshortandlongterm	Expensive for short and long term
Storage capacity	Small storage space	Large storage space
System waste	Environmentally friendly distilled water.	Environmentally harmful gas emission
Scalability	Scalable	Scalable
Efficiency	---	Below 70%
Cost of large scale	Very low compared to batteries	Very high

Regarding the environmental impact, HHO cell s considered as a green energy element that no bad effect on the environment as its wastage is distilled water and can be used for drinking whereas the batteries cause pollution because of the leakage of chemical substance or gases emission emerging from the batteries that may cause harm for people, animals and earth. Moreover, although the construction cost of small scale HHO is more expensive than battery as it still in the research phase, large scale facilities are much less cost than large scale batteries storage facilities. Also, large scale facilities of HHO cells provides much higher lifetime and larger storage capacity with no harmful effect as well as no recycling stage is needed in the. Both technologies are scalable since the size of the storage element will vary depends on the application type. The efficiency for the battery was found to be around no more 70% whereas the efficiency of HHO cell could not be determined because HHO cells are in research phase and it's an application dependent technology [21]. It's expected to be much lower and as farther research development expected to increase. To evaluate the HHO efficiency, we provide a case study of analyzing the use of different batteries with the fuel cell for electric vehicles as illustrated in fig.1.

Figure 1: Storage volume versus the driven distance in Km for electric cars and normal cars

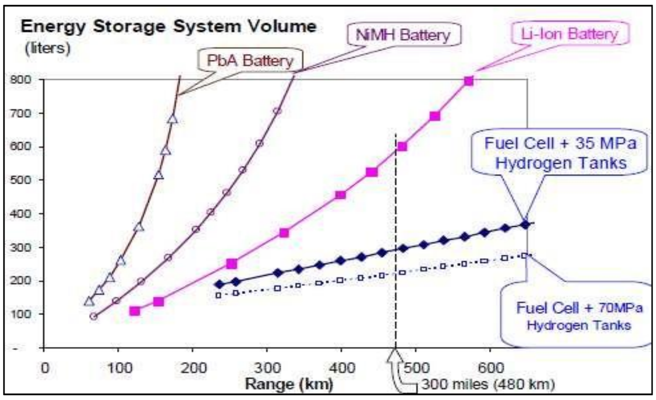
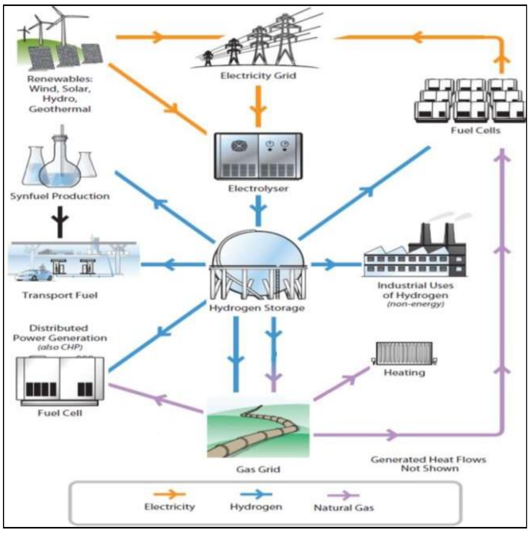
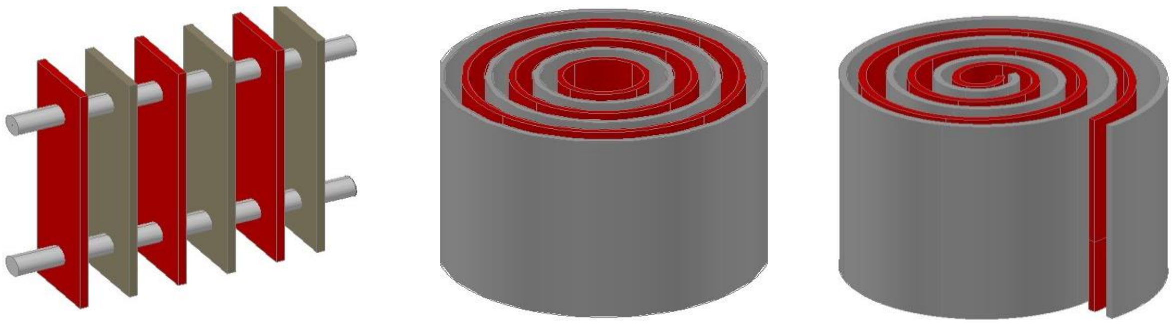


Figure 1 shows the comparison in terms of storage volume versus the vehicle range for different types of batteries and fuel cell [22]. Note that, HHO cell has similar principle to the Fuel Cell, however it has the reversal operation of fuel cell. Thus, the fuel cell characteristic can be applicable to the HHO cell. According to the figure, the storage volume in liters for PbA Battery, NiMH Battery, Li-Ion Battery and Fuel Cell (Hydrogen Tanks) are compared with the range in kilometer that the electric car will drive based on the amount of energy storage system volume. Fuel cell has shown great results compared to the Li-Ion battery which is more efficient battery among the compared batteries. Fuel Cell with volume of 300 liter for hydrogen will make the electric car drive around 480 km. While for Li-Ion battery a volume of 600 liter will drive the electric car around 480 km. It can be concluded that the efficiency of the fuel cell is almost twice the Li-Ion battery. Along with these results, it counts for HHO cell in term of efficiency.

Figure 2: Proposed integrated energy network using water electrolysis to produce hydrogen as an energy carrier [23].



Unlike the previous researches, in this paper we will optimize new HHO generator cell that can be used for green communities and future power systems. Figure 2 shows the proposed diagram that shows the hydrogen usage cycle in the energy scheme. Also, we will consider three different designs for the Hydrogen generator cell: Square parallel plates, Cylindrical pipes and Spiral plates as shown in figure 3.



(a) (b) (c)

Figure 3: (a) Parallel Plates Design for HHO Cell, (b) Cylindrical tubes Design for HHO Cell, (c) Spiral Plates Design for HHO Cell

The proposed designs are trying to increase the output of gas while decreasing the input of current which make some designs are more effective than others. The pales in any form (Square, Cylindrical or Spiral) are made from stainless steel 316 and uses regular rubber O-rings to separate them with reduced amount of input current and they can be designed as wet cells in which plates or tubes are submerged in water or as dry cells where the water run through the plate [24]. The dry cell design is cheaper and can vary in shape or size, making it very easier to install anywhere whereas the wet cell design encompasses complicated manufactured process and thus its more expensive. However, the effectiveness of wet cell system is higher than the dry cell system, although more current input is necessary the amount of hydrogen out is greater. Therefore, in this work, we propose to use the wet cell system design. Moreover, for every single design, the chemical and electrical properties are considered to obtain the relations that represent the behavior of the design. Furthermore, different types of water such as distilled water, tap water and saltwater is used to observe the best responses of the electrolysis and different methods of tuning the electrical input were applied to optimize the hydrogen emission. Finally, experimental results are reported for purpose of benchmarking of the three designs to determine which design is more efficient in terms of supplied power and amount of Hydrogen produced.

3. WATER FROM CHEMICAL PERSPECTIVE

Water is a chemical substance (H2O) where one molecule of water consists of two atoms of hydrogen covalently bonded with a single atom of oxygen. Water has several properties such as it is a tasteless, odorless and appears colorless in small quantities. In addition, the boiling point of the water is 99.97 °C ≈ 100°C, the melting point is 0 °C, with density of 999.97 kg/m^3 and molar mass of 18.01528 g/mol. The chemical structure of water in its different formulas is giving in fig. 4: fig.4(a) shows the structural formula of water molecule on a plane, fig.4(b) shows how the water is a V-shaped molecule with angle between the atoms equal to 104.5 degree, fig.4(c) discribes the covalent bond of water by using Lewis dot symbols, fig.4(d) displays the liquid water structure; where the electrostatic attractions (dotted lines) held the water molecules together by the partially negative charge of oxygen atom with the partially positive charge of hydrogen atoms on adjacent molecules. Liquid water does not have one fixed structure because the connections between water molecules are continually breaking and restructuring. Fig.4 (e) shows a space-filling model of liquid water.

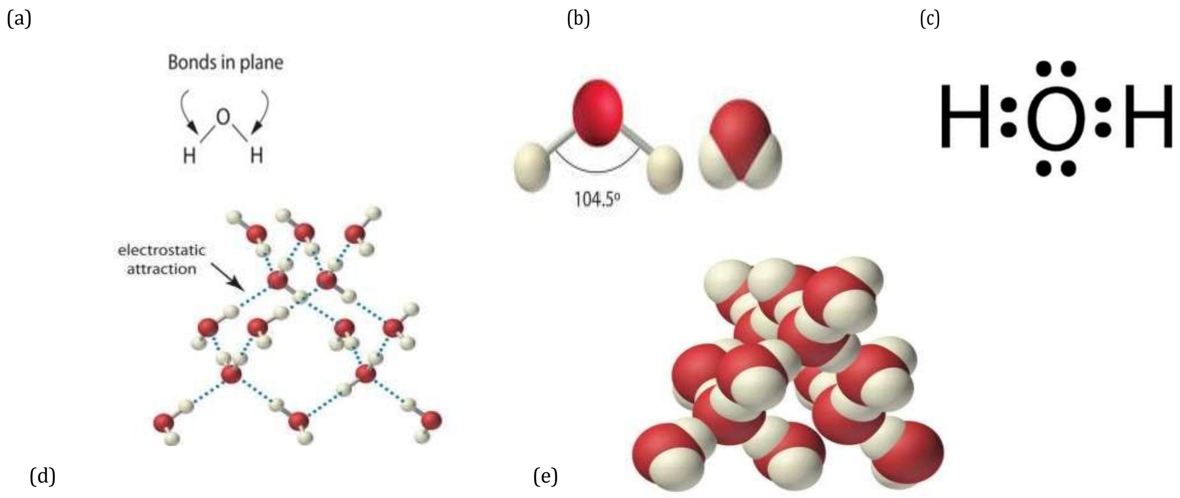


Figure 4: (a) Structural formula of water molecule on a plane, (b) Water is a V-shaped molecule, (c) Lewis dot symbols to describe covalent bond of water, (d) A ball and stick structure of liquid water and (e) A space filling model of liquid water.

Also, fig.5 shows the polar nature of water [25]. The covalent bond between O–H, which represent the oxygen atoms, attracts electrons more strongly than the hydrogen atom does. Consequently, it can be observed that the oxygen and hydrogen nuclei do not equally share electrons [26]. Hydrogen atoms have a partial positive charge represented by δ+ and its low compared with the neutral hydrogen atom. On the other hand, oxygen atom is more electron rich than a neutral oxygen atom, so it has a partial negative charge. The partial negative charge must be twice as large as the partial positive charge on every hydrogen for the molecule to have a net charge of zero. Thus, its charge is indicated by 2δ–. This unequal distribution of charge makes a polar bond, in which one portion of the molecule carries a partial negative charge, while the other portion carries a partial positive charge because of the arrangement of polar bonds in a water molecule; water is described as a polar substance.

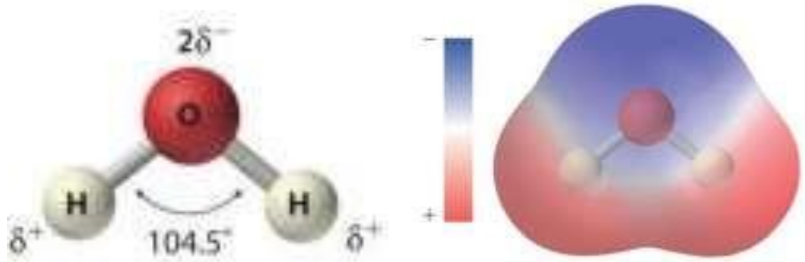


Figure 5: Polar nature of water

The water electrolysis is the process of splitting water into its basic elements by passing an electrical current through. Electrolysis process required two electrodes, positive electrode (anode) and negative electrode (cathode). Both electrodes are immersed in water to be electrolyzed. The electrodes are connected to a source of electric current {reference number} which can be DC or AC current. When electricity is introduced to water, the ions are attracted to the opposite charged electrodes. Therefore, the cathode will collect the positive charge (hydrogen) and the anode will collect the negative charge (oxygen). Electrolysis reaction described in the following equations [27, 28]:

Anode (oxidation): $2H_2O(l) - 4e \longrightarrow O_2(g) + 4H^+(aq)$ with $E^\circ = 0.408V$ .... *Equ. (1)*

Cathode (reduction): $2H_2O(g) + 2e \longrightarrow H_2(g) + 2OH^-(aq)$ with $E^\circ = 0.822V$ .... *Equ. (2)*

Overall reaction: $2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$ with $E^\circ = 1.23V$ .... *Equ. (3)*

Thus: Cathode side: $2e^- \rightarrow H_2(g)$: $e^- = \frac{1}{2}H_2$ *while the Anode side:* $-4e^- \rightarrow O_2(g)$: $-e^- = \frac{1}{4}O_2$ .... *Equ. (4)*

If two electrons pass from cathode to anode, they will release H2 and O atoms. That means each electron will release *H* and□ *O* . In this project, we need to determine the amount of produced Hydrogen and Oxygen. To determine that we need to calculate the volume for one mole of 2H2+O2. The volume for one mole is given by [29]: pV ⁇ nRT . Where, p is the gas pressure, V is the gas volume, R is the gas constant, n is the number of moles and T is the temperature. Also, equation (5) can be rewritten as: V = nRT P. Now, considering T = 298 K, R = 0.0821 (atm.L.K-1.mol-1) for Hydrogen,

P = 1atm, and n = 1 then the volume of one mole of hydrogen is calculated as: $V = ((1)(0.0821)(298))/1 = 24.46\ L$. Also, regarding the energy of (1) mole of water, the standard molar enthalpies of liquid water (H2O(l)) at 298 K (25oC) [30]:

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) + 572kJ\ (286kJ/mole)$ ……… ***Equ. (6)***

Hydrogen gas is one of the highest energy density values per mass [30]. Each 1 kg of mass of hydrogen contain an energy value of 120-142 MJ. Hydrogen is highly flammable gas, it only need a small amount of energy to burn. When the hydrogen burned with oxygen, it will produce only heat and water (clean burning). However, at ambient conditions (300 K, 1 atm.); the energy content of 1 liter of H2 is only 10.7 kJ. If we need to calculate the required energy to break the water bond, it is necessary to know the bond length(s) and angle(s). Bond length(s) is the distance between the nuclei of bonded atoms, whereas the bond angle(s) is the angle between adjacent lines representing bonds. For H2O, bond length between O-H is 95.84 pm (Pico Meter "**1 × 10□12**") and the bond angle is 104.45o (degree).

Figure 6 shows the relation between the potential energy and inter-nuclear distance of the bond between O-H. It is clear from the graph that the maximum energy is released when the ions are close to each other (at r = 0). It can be observed that at very short distances between electrons the bond become very stronger, so it needs huge amount of energy to breakdown the bond 'Region 4 in the graph'. In addition, the total energy of the system reaches a minimum at r0, (the inter-nuclear distance (r0) of O-H is 95.84≈96 pm), where the electrostatic repulsions and attractions are exactly balanced 'Region 3 in the graph'. As long as the inter-nuclear distance increase (r ≈∞), the amount of energy required to break the bond will increase gradually 'Region 2&1 in the graph'. The conclusion of this graph is that at r0, the ions have a lower potential energy than they are at an infinite inter-nuclear distance. Thus, designing an efficient system for splitting water into hydrogen and oxygen, driven by sunlight is among the most important challenges facing science today, underpinning the long-term potential of hydrogen as a clean, sustainable fuel [31].

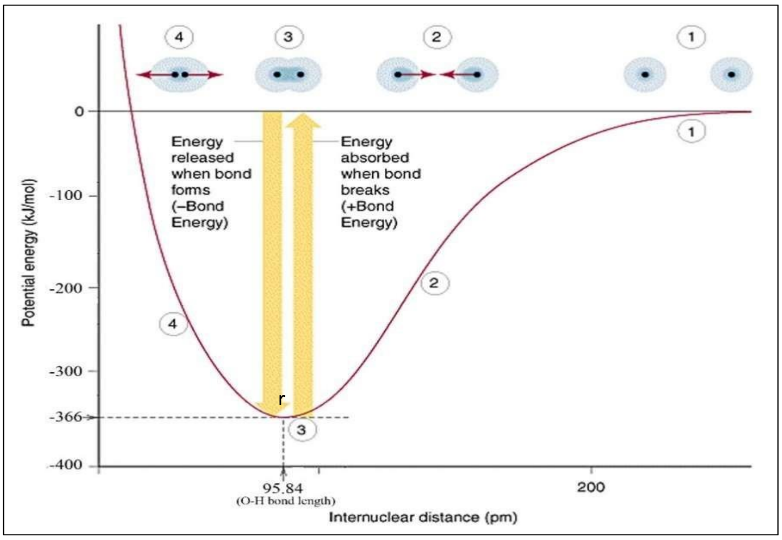


Figure 6: Curve of minimum energy required to break the water bond.

4. PROPOSED SCHEMATIC DESIGN OF HYDROGEN GENERATOR CELL

Water electrolysis technology is used to produce hydrogen for industrial processes due to its potential to be coupled with several sources of renewable energy such as wind and solar power. It can operate effectively with fluctuating electrical input and can be implemented at wide range of scales. Simply, the cell uses electrical pulses to separate the water ions to its Hydrogen and Oxygen components as in the following chemical equation, and the relation between the different electrical pulse's types and the separating distance of the atoms is illustrated in figure 7.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g) \qquad Equ.\ (7)$$

As illustrated in figure 7, the frequency and the shape of the electrical pulse is set in such a way that induces a resonance within the water molecule. By using critical number of electrical pulses, the hydrogen – oxygen bonds will be broken efficiently [32]. Water electrolysis occurs when an electric current used to split water into hydrogen and oxygen by placing two electrodes into the liquid and connecting a battery across them; the gases can be produced under pressure. When an electric current is applied to electrodes, hydrogen gas is formed at the cathode (-) and oxygen gas at the anode (+). The main rule of electrical energy is to force the reaction which causes water to dissociate into hydrogen and oxygen [33]. The proposed hydrogen generator cell is depicted in fig.8 (a). Unlike electricity, the hydrogen produced by the electrolysis process is a clean energy source that can be stored in large quantities for long periods with cost-efficient. The use of hydrogen as a clean energy source is very advantageous as it can link different forms of energy uses which allow for more efficiency, more integration and more flexibility overall. As seen in fig.8 (a), the hydrogen produced by the electrolysis process (driven by either grid electricity or renewable energy) can be stored and then used in different ways such as a vehicle fuel or can be supplied to industry as a raw material, or chemically combined with carbon to produce synthetic hydrocarbon fuels.

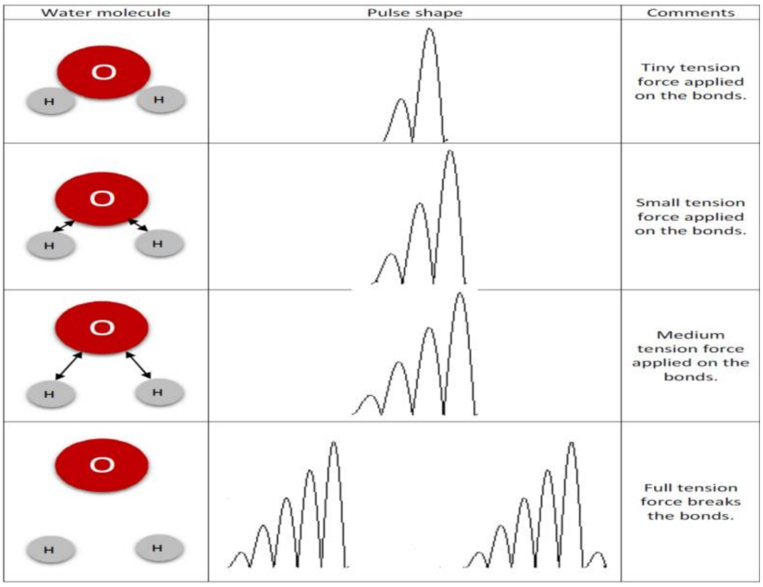


Figure 7: Illustrations of the relation between the different types of electrical pulses and the separating distance of the atoms.

On the ethical level, Hydrogen generator cell design must be consistent with the safety, health, and welfare of the public and factors that might endanger the public or the environment to be disclose promptly. According to the fact that hydrogen gas is highly flammable and will burn in air at a very wide range of concentrations between 4% to 75% by volume, both electrodes and plates of the cell will be totally immersed in water to prevent any contact with produced gases as a precaution to prevent any explosion due to electric spark via the current passing through the electrodes. Also, there will be water level controller using optical sensor to compensate the water level inside the container via electric valve to keep the plates immersed in water. Moreover, the produced gases from the cell container is passed through a pipe to another container (bubbler) which contains water to isolate the gases produced at stage 1 from the gases delivered to stage 2. More stages of bubbler can be added to insure the safety.

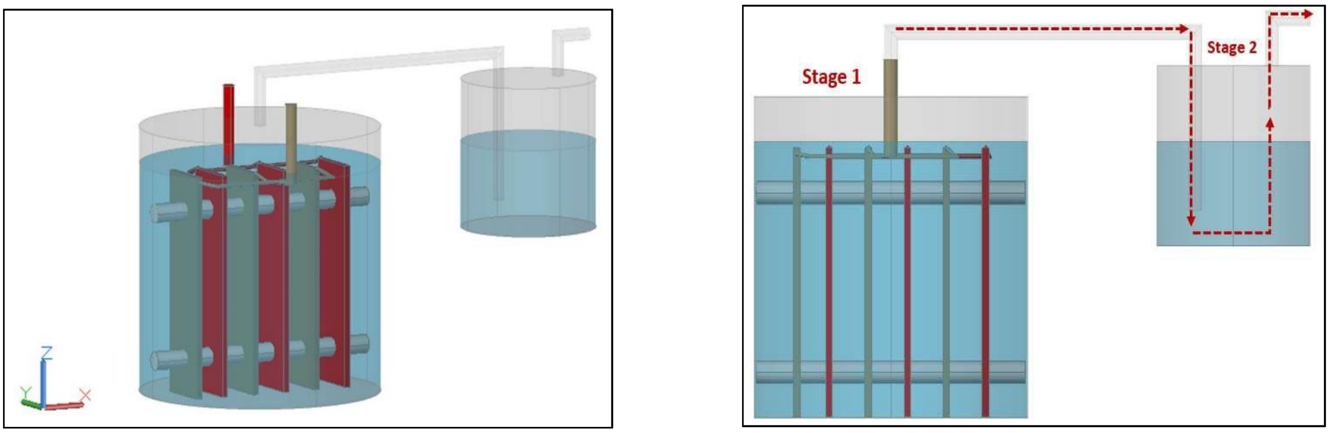


Figure 8: (a) Hydrogen Generator Cell design (b) Proposed gas flow for the system of HHO cell

Figure 8 (b) shows the proposed gas flow system for the cell. Using the bubbler, any unexpected spark happened at stage 2 will not be extended to stage 1 due to the isolation medium (water at stage 2). Furthermore, the HHO generator cell will be contained in plexiglass container to enclose the system as another safety measure and precaution for any further danger. A hydrogen sensor is suggested to be installed as an alarm system to detect hydrogen leakage. As safety always been the first rule for engineers, so every single step in the design is analyzed in terms of safety to achieve the overall safety of the system. Fig.9 shows proposed system design with safety features for the cell.

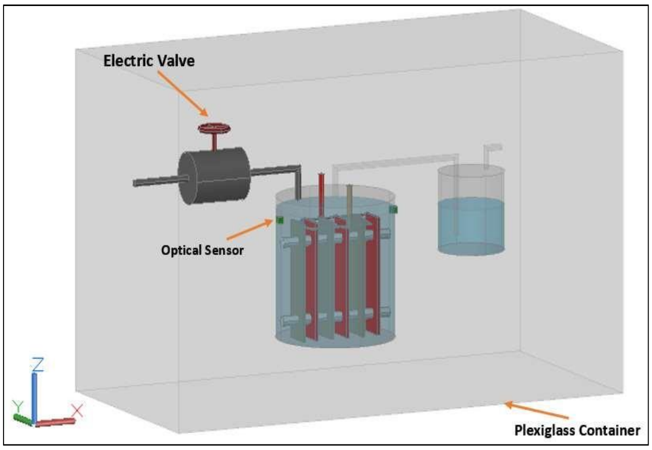


Figure 9: Proposed HHO cell design with the safety features

On the social level, the green energy storage system will have no bad impact on the society if it's implemented properly with all safety requirements. The distinguished feature is that input and output of HHO cell is water which is natural compound. Also, it will reduce the percentage of pollution that occur via producing or recycling the batteries as it also lasts for much longer times than the batteries. Moreover, storing H2 is not different from storing C_3H_8 which every house uses, and it can cause explosions if leaked. Therefore, no need for fear of storing the H2 if the safety precautions have been considered. Finally, the encasing of the earth, namely the water and air, have been polluted far beyond its capacity to clean itself which calls urgent actions to rectify the situation of the environment or there will be a day when the environment around us would collapse to make survival near impossibility [35-37]. In this work, we are contributing to reduce the pollution emitted from the batteries as it will promote a green energy generation and storage that can change the path of life in a good way.

5. ESTIMATED COSTS

Table 2 shows the components needed to accomplish the system design along with their estimated cost. Few points must be mentioned to clarify the table, as engineers the cost of the component must be determined and estimated carefully to achieve the project with minimum cost. Minimum cost does not mean to choose the low-priced equipment while neglecting its quality. That does not mean to choose a high-quality component and exceed the budget limits. It is a tradeoff mechanism that it can be handled by the engineering sense. One of the basic items in this project is the stainless-steel sheets, to design an efficient design, it is necessary to select an original stainless-steel sheets and bolts to avoid the corrosion and rust problem after certain period. In addition to that, stainless steel need some special equipment to cut or shape it and that will be counted under accessories. Next item is two containers, one for the electrolysis operation and the other one is used as a bubbler for safety concerns. After investigating the available containers, we found that the water filter that made for home uses could be used in the project as a container. The filter design allows for enough gas pressure and type of seal that needed for the cell. At the same time, its cost is much lower than custom designed container. Another important item used is the microcontroller (Arduino); Arduino allows users to write programs using C or C++ languages. The purpose of using the Arduino is to create the shape of the pulses that can give us the maximum amount of hydrogen. Furthermore, it is necessary to use a high-power FET-transistor and resistors to generate the output signal that will be delivered to the cell to produce the HHO gas. Moreover, safety means must be included in the design to ensure that the working environment is safe and in case of emergency the damages will be very low. To maintain the safety, the system will be surrounded by a plexiglass to protect the people whom working on it. Also, safety glasses will be provided during the working hours. Optical transceiver sensor used for safety purpose to keep the plate immersed in the water, which mean if the water level decreases the electric valve will be activated to fill in the container by water.

Table 2: List of needed components and its approximate cost (For three unit).

	Item	Quantity	Description	Estimating Cost in US$
1	Stainless steel sheet	2	1m*1m (0.5mm)	130
2	Stainless steel tubes	4	Different sizes	80
3	Container	6	Water filter	80
4	Electrical wires	---	---	30
5	Stainless steel bolts	---	---	50
6	Plastic bolts	---	---	20
7	Hoses	---	0.5" or 0.25"	40
8	Silicon	6	---	20
9	Switch	10	---	30
10	Microcontroller	3	ARDUINO	140
11	Voltage Regulator	6	---	10
12	Mixer	3	---	30
13	FET transistor	6	High power	80
14	Solder	3	---	10
15	Resistors	6	High power	25
16	Resistors	Group	Low power	15
17	Capacitors	Group	Low power	10
18	Plexiglass	3	Safety uses	240
19	Safety glasses	3	Safety uses	10
20	Optical transmitter sensor	3	Safety uses	5
21	Optical receiver sensor	3	Safety uses	5
22	Electric valve	3	---	40
23	*Accessories	---	---	400
			Total Price in SR:	1500 $

6. CONCLUSIONS AND FUTURE WORKS

Sustainability, reliability, low cost and environment friendly are main features that are required to be exist in energy sources. Recent renewable energy systems may not satisfy all these features, so a replacement for some of the sub-systems may lead to enhancement of the overall system. In this paper, the photovoltaic system is considered as the renewable energy source and HHO cell is sub-system replacement for the energy storage system batteries. HHO cells have overcome many of the batteries' problems such as environment impact, reliability, pollution, cost and feasibility. Thus, three design alternatives have been proposed for the internal plates (Parallel, Cylindrical and Spiral) each of which can be modeled into electric circuit to calculate the plates parameters i.e. resistance, inductance and capacitance. Accordingly, this work can be extended to cover up the mathematical modeling and comparison to determine the optimum design in addition to the hardware design implementation as well as the design benchmarking and evaluations. The next stage of this work is designing the physical cell and operate in field to gain more insight of the cell operational capabilities. Finally, extensive experimental results for the plate's parameters such as resistance, inductance and capacitance can be found in our integral part of this work in, to get more insight into the proposed designs. However, the simulation data showed that minimizing the voltage at least to be 1.23V, will increase the effective current, hence improving the efficiency.

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