PV integrated on-demand water electrolysis system for HHO generation and its application as primary fuel in combustion

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Abstract. The brown’s gas also known as HHO gas has been produced using dye cell alkaline water electrolyser using 316L stainless plates. The electrolyzer has been integrated with solar panel using battery bank and charge controller to develop on-demand HHO generation system. The produced gas has been employed as primary fuel for combustion and its effectiveness has been investigated. Preliminary observations revealed that the photovoltaic (PV) integrated alkaline water electrolysis system exhibits smooth operation and provides proper control over the production process. On the other hand, the utilization of HHO gas as primary fuel displayed highly satisfying results. The developed system has the capacity to generate HHO on the order of 3L/min at 15Amps and it almost instantly burn paper and acrylic sheet.

1. Introduction
The industrialized modernization and human growth is much reliant on the high calorific value energy sources such as fossil fuels which are already on the brink of extension. Figure 1a shows the forecasted life of fossil fuels, which forecasted life of our fossil fuel reserves due to high excavation rates. Other associated problem is our inappropriate technology to harness useful energy from fossil fuels which cause high emissions of greenhouse gases and increase in CO2 concentration in global environment. Figure 1b is showing CO2 concentration for the past 400,000 years, where CO2 concentrations have shown several cycles of variation from about 180 ppm to 280 ppm. The concentration has increase dramatically from past 200 years due to industrial revolution and the CO2 concentration reached to 400ppm [1].
Figure 1. (a) depletion of fossil fuels and (a) global CO2 emission history [1].

Much emphasis has been given to renewable energy systems and their effectiveness have been successfully demonstrated [2]. In this regards, chemical storage and on demand use in the form of hydrogen is a lucrative option. Water can be electrolyzed using electricity from solar panels and used to generate electricity or heat energy when required.

Water splitting composed of two half reactions including hydrogen evolution reaction (HER) and oxygen evolution reaction (OER) but efficient water splitting can be achieved by efficient electrocatalyst to facilitate HER at the cathode and OER at the anode. Currently, Pt group metals and Ru/Ir-based compounds are the state-of-the-art, noble, efficient HER and OER electrocatalysts respectively with low overpotential and Tafel slope. However, these noble electrocatalyst suffer from high cost, scarcity that limiting its application to produce hydrogen resource economically by water splitting. Moreover, the cell potential of the commercial water electrolyzers (1.8e2.0 V) are about 570 - 770 mV higher than the theoretical minimum value (1.23 V). Since hydrogen production through water splitting is energy intensive process, much of the efforts have been put forwarded to integrate the hydrogen with renewable energy sources. The second most crucial task is hydrogen storage and transportation. As H2 is highly explosive gas, great care is needed to store it with high capital investment and safety infrastructure. These safety issues become more pronounced when talking about HHO gas because this gas itself contains oxidizer in exact stoichiometric ratio. A new approach for efficient utilization of HHO gas is its on-demand production which attracted the attention of various research communities and policy maker circles.

The utilization of HHO in combustion process has been extensively investigated with impressive results. HHO when mixed with other combustion fuels such as natural gas, petrol and liquid petroleum products increase their combustion efficiency [3]. Attempts have been made to substitute some forms of petroleum products altogether with H2 and/or HHO with successful results. HHO has high potential in metal welding and cutting industry and bound to replace unsafe oxyacetylene welding and cutting apparatus. H2 has also been utilized in melting furnace in different proportions. Authors claimed improvement in combustion efficiency and cost effective process [4-6].

In this work, we design dry cell alkaline water electrolyzer and integrated it with solar PV for the production of HHO gas. Another objective of the study was to investigate the utilization of HHO gas as primary fuel for combustion.

Water electrolyzer setup:
A 30 plate dry cell alkaline water electrolyzer kit has been purchased from “greenfuel H2O” (Figure 2).
Figure 2. 30 plate dry cell water electrolyzer

It contains 30 316L stainless steel plates with 5inches active area. No neutral plates have been utilized in cell configuration with 2 volt plate gap based on 12 volt power source. Note that this information has been provided by the supplier. The system has been initially installed in lab to test its performance. Figure 3 shows inside setup of the system. A 64Ah, 12V car battery has been utilize to energize the electrolyzer.

Figure 3. indoor setup of the system

The current has been limited to 15Amps as recommended by the supplier. A maximum of 3L/min HHO gas flow has been measured (using inverted water bottle) at 15Amps after 15min of running.

2. PV integrated water electrolysis system

The system has been integrated with PV panel with rated power of 300W. A charge controller has also been installed to properly charge the battery. The electrolyzer has been directly coupled with the battery and an on/off breaker has been installed between electrolyzer and the battery to function as on/off switch and circuit breaker. Figure 4 shows outdoor setup of the system. Figure 5 shows the electrical wiring and battery connections of the system. Water bubblers and moisture filters have also been installed for safety purpose and removal of water respectively. Flashback arrestor has also been employed to avoid any flash backs.
Combustion nozzle:
An appropriate torch with nozzle orifice 0.3mm has been utilized for proper control over the flame and to arrest the flashback. Figure 6 shows the torch employed for this purpose.

Normal paper and acrylic sheets have been tested to study the proper functioning of the flame. The flame temperature according to literature is approximately 2600-2800°C [7]. The flame was almost invisible in broad day light. It take only 3 seconds for the flame to inflame acrylic sheet (1cm thick). And the paper has been instantaneously got flamed when it came in contact with the flame. Figure 7 shows inflamed substrates.
3. Conclusions
In this study, PV integrated water electrolysis system has been developed to generate HHO/brown’s gas. A safe and controlled flame has been achieved by burning the HHO gas employing suitable torch with orifice size 0.3mm. flashback arrestor has also been installed to avoid dangerous flashbacks. The system generated capacity was calculated to be 3L/min. The flame almost instantly burn paper and acrylic sheet then came in contact.

4. Future work
The present will prove to be a starter in the field of on-demand HHO utilization. The system will be extended to metal welding/cutting and aluminum melting furnace operations.

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