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Production Of Green Hydrogen Using Solar-Powered Electrolysis: A Sustainable Approach To Energy Transition

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Abstract: Green hydrogen, produced by the electrolysis of water using renewable energy sources, offers a clean and sustainable solution to reduce global dependence on fossil fuels. This research explores the design, implementation, and performance analysis of a solar-powered HHO (hydrogen and oxygen) generation system. A prototype setup utilizing a 100W solar panel, a 12V battery, and a stainless steel electrolyzer demonstrated successful hydrogen production with an energy efficiency of approximately 75%. The study highlights the environmental benefits, economic implications, and potential for future scalability of such systems, while addressing key challenges such as system efficiency, weather dependency, and infrastructure limitations. This paper contributes to the growing field of green hydrogen technology and presents a practical approach toward decentralized, emission-free hydrogen production.

***Index Terms* - Green Hydrogen,HHO Gas,Electrolysis,Renewable Energy,Solar Power**

I. Introduction

II. The transition from fossil fuels to sustainable energy sources is imperative to combat climate change and achieve energy security. Hydrogen, a clean and abundant element, is gaining prominence as a versatile energy carrier. Particularly, green hydrogen—produced via electrolysis powered by renewable energy is an emerging solution for decarbonising sectors like transportation, industry, and power generation. This project investigates the feasibility of solar-powered HHO gas generation to meet small-scale energy demands sustainably.

2. Literature Review

Green hydrogen has emerged as a significant research area in the context of sustainable energy. Bibliometric reviews indicate a growing focus on integrating hydrogen production with renewable energy systems. Studies have explored the efficiency of electrolysis methods, storage challenges, and the economic feasibility of hydrogen-based technologies. HHO gas, a product of water electrolysis, finds application in fuel cells, welding, and combustion engines. Countries like India have initiated strategic programs, including the National Green Hydrogen Mission, to promote large-scale hydrogen adoption.

Literature Review

1. Introduction to Hydrogen and HHO Gas

Hydrogen is widely recognized as a clean energy carrier due to its high energy density and zero-emission characteristics upon usage. One promising variant is HHO gas (Brown's Gas), a 2:1 mixture of hydrogen and oxygen generated through electrolysis. HHO has multiple applications in energy and industrial sectors due to its clean combustion properties. The transition to hydrogen-based fuels is seen as a critical step in global decarbonization efforts.

2. Hydrogen Production Techniques

Traditional hydrogen production methods include:

- **Steam Methane Reforming (SMR)** – most common, but emits CO_2.
- **Coal Gasification** – cost-effective but highly polluting.
- **Biomass Conversion** – sustainable but not yet scalable.
- **Electrolysis of Water** – produces green hydrogen when powered by renewable sources.

Electrolysis, although currently less economical, is the cleanest method when combined with renewable energy like solar or wind. Recent advances in electrolysis cell materials (e.g., platinum, iridium, or stainless steel) and techniques (PEM, AEM, and alkaline electrolysis) have improved its viability

3. System Design and Materials

The experimental setup comprised a 100W polycrystalline solar panel, a 12V deep-cycle lead-acid battery, and a 1L electrolysis chamber with stainless steel electrodes. A 5% potassium hydroxide solution served as the electrolyte. Supporting instruments included a gas flow meter, voltmeter, ammeter, and an Arduino-based data logging system. A charge controller ensured safe energy flow between the panel, battery, and electrolyzer.

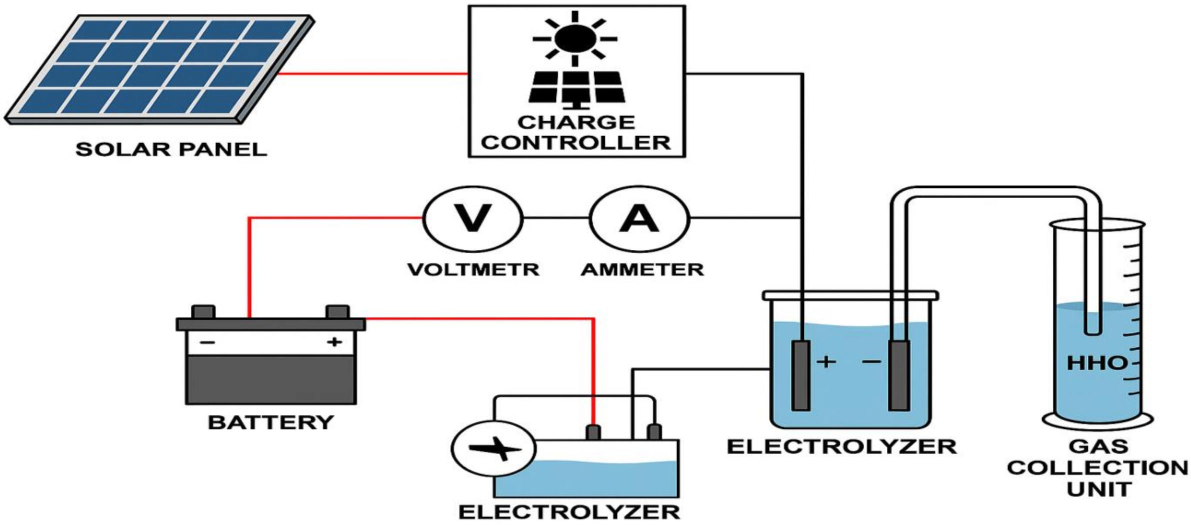

fig.(1) Production of hydrogen by using solar energy

4. Methodology

The system was assembled to optimize sunlight capture and efficient power conversion. Data was collected on gas production, current-voltage characteristics, and battery charge under varying sunlight conditions. Theoretical efficiency was compared with experimental results to evaluate system performance.

Key Parameters Monitored:

- Solar intensity
- Electrolyzer input voltage and current

Methodology

This study aimed to design, construct, and evaluate a solar-powered HHO gas generation system for the sustainable production of green hydrogen. The methodology involved several key stages, from system design and component selection to experimental setup, data collection, and performance analysis.

1. Research Approach

The project followed an applied experimental approach, combining theoretical principles of electrolysis and renewable energy with practical implementation. The primary goal was to assess the feasibility, efficiency, and environmental benefits of producing hydrogen using solar energy.

2. Experimental Setup

The system was assembled using the following main components:

- **Solar Panel**: 100W polycrystalline panel to capture solar energy.
- **Battery**: 12V, 40Ah deep cycle lead-acid battery for energy storage.
- **Electrolyzer**: Stainless steel electrodes in a 1L chamber with a 5% potassium hydroxide (KOH) solution.
- **Charge Controller**: To regulate energy flow between the solar panel and battery.
- **Gas Collection Unit**: Graduated cylinder setup using water displacement method.
- **Monitoring Instruments**: Voltmeter, ammeter, gas flow meter, and a microcontroller (Arduino) for data logging.

3. System Assembly and Integration

- The solar panel was mounted at an optimal tilt to ensure maximum sunlight exposure.
- The charge controller managed energy flow to prevent battery overcharging.
- The electrolyzer received power from the battery to perform electrolysis, producing HHO gas.
- Gas was collected in a chamber, and data such as voltage, current, and gas volume were logged and analyzed.

4. Testing Procedures

- The system was tested on various days under different weather conditions (sunny and cloudy).
- Data were recorded for parameters including solar intensity, battery voltage, current input to the electrolyzer, and volume of gas generated.
- Performance was evaluated by comparing energy input to hydrogen output, calculating overall system efficiency.

5. Safety Measures

- Electrical insulation and protective housing were applied to all live components.
- Electrolyte handling was done with gloves and goggles due to KOH's corrosive nature.
- Spark-proof equipment was used around the gas collection area.

- Fire extinguishers rated for electrical and gas fires were kept nearby.

6. Data Analysis

- **Efficiency Calculation**:

  Efficiency (%)=(Energy Output (Hydrogen)Energy Input (Electricity))×100\text{Efficiency (\%)} = \left(\frac{\text{Energy Output (Hydrogen)}}{\text{Energy Input (Electricity)}} \right) \times 100Efficiency (%)=(Energy Input (Electricity)Energy Output (Hydrogen))×100

- **Statistical Analysis**: Patterns and correlations were evaluated between variables such as solar intensity and gas production rate.
- **Trend Analysis**: Daily logs were used to identify long-term performance consistency and improvement areas.

5.Conclusion

The successful implementation of a solar-powered HHO (hydrogen and oxygen) gas generation system demonstrates the practical feasibility of producing green hydrogen through renewable energy sources. By harnessing solar energy to power electrolysis, the project achieved hydrogen production without reliance on grid electricity or fossil fuels, offering a clean and sustainable energy alternative.

The system, comprising a 100W solar panel, 12V battery, and stainless-steel electrolyzer, achieved an electrolysis efficiency of approximately 75% under optimal sunlight conditions. While the system performed well on sunny days, performance was notably impacted during cloudy conditions, highlighting the weather dependency of solar-powered hydrogen production. Nonetheless, the use of battery storage effectively supported energy supply during low-light periods.

The project identified key benefits of green hydrogen, including zero greenhouse gas emissions during production, potential for application in transport, industry, and residential sectors, and support for India's vision of becoming energy-independent. However, it also acknowledged limitations such as high capital costs, storage challenges, and limited infrastructure.

In conclusion, the integration of solar power with hydrogen production offers a viable path toward clean energy solutions. With further research into improving electrolysis efficiency, reducing costs, and enhancing system scalability, green hydrogen can significantly contribute to global decarbonization goals and India's National Green Hydrogen Mission.

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