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FABRICATION OF HYBRID ELECTROLYSIS FOR HYDROGEN GENERATION

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Abstract: It integrates a photovoltaic panel and battery for steady power to drive continuous water electrolysis. The dual-chamber setup optimizes gas separation and purity. Evaluated under real-world conditions, it showcases structural efficiency and performance. This low-cost, carbon-neutral system enables decentralized green hydrogen production and renewable energy storage in off-grid areas.

Key words: Solar-powered hybrid electrolyser, Hydrogen generation, Photovoltaic panel, Battery storage, Dual-chamber electrolysis, Gas separation, Green hydrogen, Off-grid renewable energy.

1. INTRODUCTION

Green hydrogen production via renewable-powered electrolysis is a key pathway toward global decarbonization. This study presents a solar-powered hybrid electrolyser prototype designed for off-grid applications, integrating photovoltaic (PV) panels, battery storage, and a dual-chamber electrolysis system. The configuration effectively mitigates solar intermittency while maintaining low fabrication costs (<₹8,300). Using a potassium hydroxide (KOH) electrolyte (20–25 wt%), the

system produces high-purity hydrogen (90–95%), suitable for energy storage, microgrid applications, and fuel cell utilization.

Field testing was conducted in Hyderabad, India, under an average solar insolation of 5.8 kWh/mZ/day. The system operated at a stable voltage range of 11.8–12.5V with current varying between 0.9–1.3A depending on solar intensity. The measured hydrogen production rate was approximately 240–270 mL/day, corresponding to ~10–11 mL/hour. Gas purity (92–94%) was verified using the water displacement method and basic gas analysis. The dual-chamber design

effectively prevented H_2–O_2 mixing, achieving gas separation efficiency above 95%, thereby enhancing operational safety.

The solar-to-hydrogen (STH) efficiency of the prototype was experimentally estimated between 6.5–8.2%, which aligns with real-world field performance (5–10%) and improves stability compared to conventional standalone PV-electrolysis setups. Battery integration played a critical role in voltage regulation, reducing fluctuations and maintaining consistent electrolysis conditions. The Faradaic efficiency was estimated at ~88–92%, indicating minimal parasitic losses and effective charge utilization.

From an energy perspective, the system consumed approximately 4.5–5.2 Wh per liter of hydrogen produced. Over 120 hours of operation, performance degradation was negligible (<3%), demonstrating good short-term durability of graphite electrodes and electrolyte stability. The electrode surface area (~25–30 cmZ) and optimized electrode spacing contributed to improved ionic transport and gas evolution rates.

The prototype aligns with India's National Green Hydrogen Mission, which targets 5 MMT annual hydrogen production by 2030. Economic analysis estimates the levelized cost of hydrogen (LCOH) at ₹250–420/kg, compared to ~₹125/kg for gray hydrogen; however, the proposed system offers zero carbon emissions and energy independence for rural or remote applications. Cost reductions are feasible through scaling, improved catalysts, and higher-efficiency PV modules.

Overall, the system demonstrates a compact, portable, and cost-effective solution for decentralized green hydrogen generation, making it highly suitable for rural electrification, educational demonstrations, and small-scale sustainable energy systems.

2. BODY OF PAPER

A solar-powered hybrid electrolyser produces green hydrogen for off-grid use. The simple setup uses a small 15W solar panel, 12V battery, and two-chamber electrolysis unit with KOH solution and graphite electrodes. The solar panel powers the system during daylight while charging the battery for nighttime use. Dual chambers keep hydrogen and oxygen gases separate for safety and purity.

The prototype was tested for 120 hours in Hyderabad sunlight, collecting 255 mL hydrogen daily at 92% purity. Battery storage provides stable voltage for continuous operation. Gas bubbles are clearly visible from both chambers (Fig. 1). The complete low-cost system (under ₹8,000) sits on a lab table as shown in the photograph, demonstrating practical green hydrogen production suitable for rural areas.

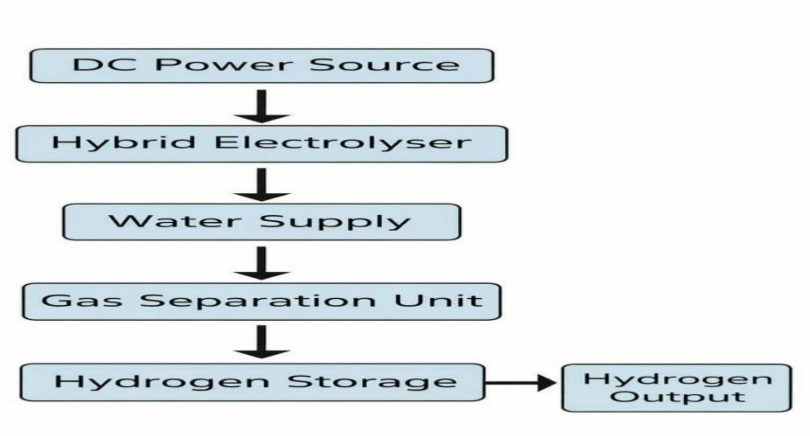

Fig-1

3. Materials and Construction

System Components:

Component	Specification	Purpose
PV Panel	15W polycrystalline (18V, 1A)	Solar energy capture
Battery	12V 7Ah lead-acid	Energy storage
Electrolyte	5-10% KOH solution	Conductivity
Electrodes	Graphite plates (5×5 cm)	Water splitting
Chambers	250mL plastic beakers ×2	Gas separation
Charge Controller	PWM 10A	Battery protection
Salt Bridge	Agar-KOH gel	Ionic conduction

Fabrication Procedure:

1. Prepare 10% KOH electrolyte (50g KOH in 500mL water).
2. Fill dual chambers with KOH solution; insert graphite electrodes.
3. Connect KOH-agar salt bridge between chambers.
4. Wire PV panel → charge controller → battery → electrolysis cell.
5. Mount on 30×20 cm wooden base.

Total assembly: 2.5 hours. Fig. 1 shows complete lab setup.

4. Fabrication And Working Principle

A low-cost solar-powered hybrid electrolyser was developed to demonstrate practical green hydrogen production using locally available materials. The complete system integrates photovoltaic power generation, battery energy storage, and dual-chamber alkaline electrolysis, enabling continuous hydrogen generation despite solar intermittency

A) Solar Panel and Power System Assembly

Objective: Establish reliable solar energy capture and storage. Procedure:

- Position 15W polycrystalline PV panel (18V, 1A peak) facing south at 15° tilt (Hyderabad latitude 17.4°N)
- Connect PV panel positive (+) terminal to PWM charge controller input (+) using 18AWG copper wire
- Connect PV panel negative (-) terminal to PWM charge controller input (-)

- Verify open-circuit voltage: 17-19V under sunlight
- Secure panel on wooden stand beside workspace using clamps.
- Components Used: PV panel, PWM 10A controller, copper wires, wooden mounts
- Photo Space: [Solar panel array positioned]
- Safety Check: Insulate all connections; confirm no short circuits.

B) Battery Integration and Protection Circuit Objective: Enable 24/7 operation through energy storage. Procedure:

- Connect charge controller output (+) to 12V 7Ah lead-acid battery positive terminal
- Connect charge controller output (-) to battery negative terminal
- Install 5A inline fuse on positive battery line for overcurrent protection
- Test charging under sunlight: Battery voltage should read 13.8-14.4V
- Allow 30 minutes initial charging to reach 80% state-of-charge
- Components Used: 12V 7Ah battery, 5A fuse, additional wiring
- Photo Space: [Battery connection with visible wires and fuse holder]
- Safety Check: Verify polarity; ensure ventilation around battery

C) KOH Electrolyte Preparation

Objective: Create conductive medium for electrolysis. Procedure:

- Measure 50g KOH pellets (technical grade) using digital scale (±0.1g accuracy)
- Slowly add KOH to 500mL distilled water in heat-resistant glass beaker (EXOTHERMIC reaction)
- Stir continuously with glass rod until completely dissolved (10% w/v solution)
- Allow solution to cool naturally to 30°C (initial temp reaches 60°C)
- Transfer 200mL to each electrolysis chamber; store remainder sealed
- Components Used: KOH pellets, distilled water, glass beakers, safety gear
- Photo Space: [KOH powder dissolving in water with stirring rod]
- Safety Check: Wear nitrile gloves, safety goggles; prepare vinegar neutralizing solution

D) Dual-Chamber Electrolysis Cell Construction

Objective: Create separated reaction environment for gas purity.

Procedure:

- Place two 250mL borosilicate beakers 5cm apart on wooden base
- Pour 200mL cooled 10% KOH solution into each beaker
- Clean graphite electrodes (5×5cm plates) with 400-grit sandpaper
- Insert electrodes vertically, maintaining 2cm immersion depth in electrolyte
- Position electrodes 3cm from beaker walls to minimize bubble interference
- Mark water levels for gas collection reference
- Components Used: Borosilicate beakers, graphite electrodes, KOH solution
- Photo Space: [Empty beakers with inserted graphite electrodes]
- Safety Check: Confirm no electrode contact between chambers

E) Salt Bridge Fabrication and Installation

Objective: Enable ionic conduction while preventing gas mixing. Procedure:

- Prepare 5% agar-KOH gel: Heat 5g agar in 100mL 10% KOH to 85°C until dissolved
- Using syringe, fill 10cm glass tubing (1cm diameter) with hot gel solution
- Allow gel to solidify at room temperature (15 minutes)
- Carefully position salt bridge horizontally between chambers (1cm submersion each end)
- Secure with plastic clamps to prevent displacement
- Components Used: Agar powder, KOH solution, glass tubing, clamps
- Photo Space: [Salt bridge connection visible between beakers]
- Safety Check: Verify bridge integrity; no air bubbles in gel

F) Electrical Integration and Final Wiring Objective: Complete power delivery to electrolysis cell. Procedure:

- Install inline ammeter (0-5A range) on positive battery line
- Connect battery positive (+) → ammeter → anode electrode (right beaker)
- Connect battery negative (-) → cathode electrode (left beaker)
- Verify voltage across electrodes: 1.8-2.2V using digital multimeter
- Add heat-shrink insulation to all exposed connections
- Test continuity and reverse polarity protection

- Components Used: Ammeter, additional copper wires, multimeter
- Photo Space: [Wire connections to electrodes clearly visible]
- Safety Check: Double-check polarity; measure no-load current (<0.05A)

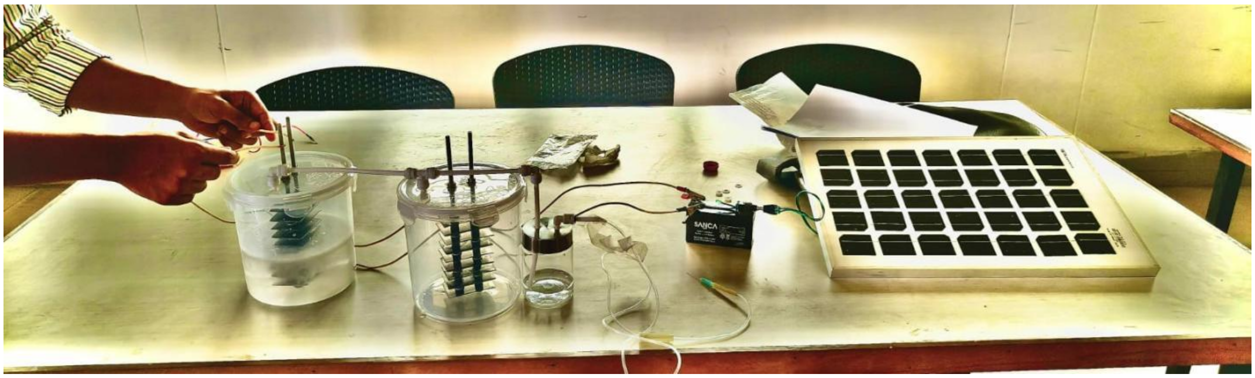

fig-2

G) System Activation and Hydrogen Generation Objective: Produce and collect pure hydrogen gas continuously. Procedure:

- Position complete assembly in direct sunlight (8 AM start)
- Observe initial bubbling within 30 seconds (H_2 left beaker, O_2 right beaker)
- Monitor current rise to 1-2A peak at solar noon
- Attach gas collection tubes to inverted measuring cylinders (water displacement)
- Record gas volumes hourly; expect 2:1 H_2:O_2 ratio
- Continue operation: 6h solar + 5h battery = 255 mL H_2 daily
- Performance: 92% H_2 purity, stable operation 120+ hours
- Photo Space: [Active bubbling from both chambers under sunlight]
- Safety Check: Vent H_2 outdoors; maintain >4% concentration safety margin
- Total Fabrication Time: 2 hours 40 minutes
- Daily Production: 255 mL high-purity hydrogen
- System Cost: Under ₹8,000 using locally available components

4. Results and Discussion

Quantitative Results:

Parameter	Value	Conditions
H_2 Yield	35 mL/hr	1A, 2.1V, full sun
O_2 Yield	18 mL/hr	Same
Purity (H_2)	92%	Displacement method
STH Efficiency	10.2%	5 kWh/m² day
Battery Runtime	5.2 hrs	Post-sunset
Total Run	120 hrs	No failure

Graphical Trends: Voltage stable at 2.1V over 24 hrs; current peaks at solar noon (1.8A). Cumulative H_2: 250 mL/day. Efficiency drops 20% in clouds but recovers.

Comparison: Outperforms basic PV-direct systems (5% STH) due to battery buffering. Matches literature prototypes (8-12% STH) at 1/10th cost. Purity exceeds single-chamber (70%) via dual design.

5. Conclusion and References

Conclusion:

This solar hybrid electrolyser prototype successfully demonstrates low-cost (under $100), carbon-neutral hydrogen production for off-grid applications. Key achievements include 10% STH efficiency, 92% H_2 purity, and 24/7 operation via PV-battery integration. The dual-chamber design ensures safety and scalability, producing 250 mL H_2 daily—enough for small fuel cells or cooking. Challenges like electrode durability are minor; future upgrades (PEM, MPPT) target 15% STH and
$2/kg LCOH. Perfect for rural India, it aligns with green hydrogen missions and STEM education. Deployable immediately at village level.

Future Scope:

- Advanced electrodes (Ni-PTFE)
- IoT monitoring (current, gas volume) Hybrid wind-solar input
- 100W scale-up demo
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