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Improve the Efficiency of Hydrogen Electrolysis with Multi Plate Electrolysis and Automated System

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Abstract*: This paper provides an introduction to the Electrolysis system. The proposed work is the future of the world's green energy generation. A fully automated hydrogen generation system is to be developed, which will also improve the electrolysis process for generating the best hydrogen output from a multi-plate electrolysis system. The model is to be developed with an automated system implementation for improving its efficiency. After that, the most important concern is hydrogen storage, so the proposed system will also develop a system that can generate maximum hydrogen in minimum working hours with minimum electricity consumption. It will be very easy to use and safe for small industries and hydrogen refueling stations. Additionally, a hydrogen leakage detector system will be implemented, which will serve as an alert system and automatically stop the electrolysis system. The hydrogen generation process improvement can be achieved with the help of multiple electrolysis plates, which will minimize hydrogen generation time and input energy. The system will display its status on a portable dashboard, showing the amount of hydrogen generated and the amount of water required for the hydrogen generation. It will also operate on a regenerative system.*

Keywords: Hydrogen generation, Efficient System, Electrolysis, Regenerative system, maximum Hydrogen generation, H2 Storage, Leakage Identification, Concentration of H2

I. INTRODUCTION

In today's rapidly evolving business landscape, companies face growing demands to expand their operations and enhance their infrastructure. The industry requires sustainable, green energy solutions to meet their power requirements, and hydrogen emerges as a viable option.

Energy is a fundamental need for human life and global development, making it a key topic in discussions and meetings focused on sustainable energy. The demand for hydrogen fuel is projected to increase significantly in the coming decades. The utilization of hydrogen as an energy source and storage method has been thoroughly examined. Hydrogen fuel is recognized as a clean alternative to fossil fuels, which are depleting rapidly and have detrimental environmental impacts due to the release of carbon oxides, nitrogen, sulphur, and other combustion byproducts that contribute to global warming.

Hydrogen fuel serves as a clean alternative energy source that can be produced from environmentally friendly sources. Currently, a limited amount of hydrogen is generated through water electrolysis using renewable energy resources, while the majority is still produced from fossil fuels. However, a multi-plate hydrogen generation system has the capability to generate hydrogen efficiently by utilizing multiple electrolysis plates, minimizing electricity input while maximizing hydrogen output. At a global level, there are four color codes used to classify hydrogen based on the nature of energy consumed by the electrolysis system: green, pink, yellow, and brown. However, the proposed system can generate energy in the form of black hydrogen, which requires significantly less energy.

II. OBJECTIVES

- Hydrogen and fuel cells have the potential to reduce greenhouse gas emissions in various applications due to their high efficiency and near-zero emissions.

- Hydrogen energy is the safest form of energy for energy-intensive tasks and is three times more potent than gasoline and other fossil-based fuels.
- Research aims to improve the efficiency and lifespan of hydrogen production technologies while reducing overall costs in terms of capital equipment, operations, and maintenance.
- Hydrogen is an efficient energy source, providing more mileage for vehicles compared to an equal amount of gasoline.
- Hydrogen fuel cells have the capacity to generate electricity with up to 65% efficiency, whereas conventional combustion-based power plants operate at around 33-35% efficiency.

III. HIGHLIGHTS

- Water electrolysis is a promising method for storing renewable energy.
- Water electrolysis enables sustainable and clean production of high-purity hydrogen.
- The overview of water electrolysis includes discussions on challenges, scientific and technological advancements.
- Rapid developments in high-performance electrocatalysts for water electrolysis are discussed.
- The implementation of a regenerative hydrogen electrolysis system utilizing a multi-plate hydrogen electrolysis system.
- Identification of the best materials for water electrolysis for hydrogen and oxygen generation.

VI. BACKGROUND

The 21st century has witnessed significant environmental changes, with climate change being a primary global concern. To address this urgent issue, the concept of converting existing hydrogen generation and electrolysis devices into black hydrogen generation with full automation and safety measures has emerged. This novel approach aims to leverage environmentally friendly hydrogen generation methods, reducing greenhouse gas emissions and dependency on fossil fuels. Water electrolysis for hydrogen production has been an established technology since the 18th century, and the process was later termed "electrolysis" by English scientists William Nicholson and Sir Anthony Carlisle.

V. IMPLEMENTATION OF THE ELECTROLYSIS SYSTEM

To maximize hydrogen production while minimizing energy and water usage, an implementation of the electrolysis system includes continuous energy supply to the electrolysis tank and the use of a multi-plate electrolyzer. The electrolysis process can be optimized by electrolyzing water with H+ ions, resulting in maximum hydrogen output. Hydrogen detection sensors, such as MQ-08, can be used to detect hydrogen levels in the system and ensure safety. The system saves 30% energy through the use of stainless steel (310L) grade, which enhances current conductivity and electrochemical properties.

Comparing the existing system's energy input and hydrogen output, modifications in the calculation show that the proposed system requires less energy (1.1 kWh for 1 kg of hydrogen) while still providing a significant energy output of 32 kWh. The system also addresses hydrogen handling issues, reducing losses associated with storage and implementing a hydrogen detection system. The control panel unit standardizes the system, ensuring better functionality and overall system health.

The proposed system utilizes normal desalinated water containing 11.71% hydrogen, which is easily electrolyzed through the electrolysis processTemperature 45^0C, isolated are from human, Follow strictly Safety precautions.

VI. OVERVIEW

This paper provides an introduction to the hydrogen electrolysis process and focuses on improving the efficiency of hydrogen generation. The aim is to meet the power needs of industries through hydrogen generation using a multi-plate electrolysis system. The system utilizes lithium-ion batteries for electricity and includes a regenerative system for energy storage. Ensuring the safety and purity of hydrogen production is crucial, particularly for industries like vehicle manufacturing. The proposed system addresses industry concerns by prioritizing operator safety, efficient hydrogen generation, regenerative power generation, and system health monitoring.

VII. PROBLEM STATEMENT

The existing hydrogen generation systems face several limitations, such as complex electrode designs, long electrolysis time, high energy requirements, inability to detect hydrogen leakage, lack of monitoring system health, and the need for frequent maintenance. These limitations result from the use of only two electrodes in the electrolysis process.

VIII. UNIQUE SOLUTION

To address the aforementioned problems, the following proposed solutions are suggested: improving the electrolysis process through the design of multiple electrolysis plates, compacting the design of electrolysis tanks to maximize hydrogen production while minimizing energy consumption and electrolysis time, and implementing an automated system with various sensors for hydrogen detection, water flow monitoring, and control panel design based on system requirements.

IX. INNOVATION/DISRUPTION/INVENTION IN YOUR SOLUTION

The proposed solution introduces automation through the use of sensors like gas sensors (such as MQ-8) and water flow sensors, providing detailed information about hydrogen production, storage, leakage detection, water usage, and time required for hydrogen generation. The design also incorporates multiple electrolysis plates to improve the efficiency of the electrolysis process. Stainless steel (310L) is identified as the suitable material for the electrolyzer, considering its composition and electrochemical properties.

X. TECHNICAL DESCRIPTION

The proposed project aims to generate hydrogen for small industries and fuel applications. It maximizes hydrogen production while saving up to 30% energy consumption. The project incorporates a self-sustaining energy generation system, eliminating the need for external energy supply. It utilizes multiple hydrogen electrolysis plates and tanks, and the generated hydrogen is further processed for deoxidization. Customized hydrogen storage tanks are employed for energy generation and industrial use. The energy generated can be used to power the electrolysis system and charge batteries for subsequent phases. The system improves hydrogen quality and includes an AI monitoring kit for ensuring system safety and functionality.

XI. METHODOLOGY

The methodology involves studying efficient hydrogen electrolyzers, including material selection, electrochemical studies, and referencing research papers on alkaline electrolysis of water. Detailed analysis of system components, their functions, and their impact on hydrogen generation efficiency and purity is conducted.

Electrode Selection: Choose suitable electrode materials based on their electrochemical properties and resistance to corrosion. Common choices include platinum, titanium, nickel, or stainless steel.

Electrolyte Selection: Select an electrolyte solution that enables efficient ion conduction and minimizes side reactions. Commonly used electrolytes include potassium hydroxide (KOH) or sulfuric acid (H_2SO_4) solutions.

Cell Configuration: Design the cell structure with multiple electrode plates separated by spacers or gaskets. The number of plates depends on the desired capacity and hydrogen production rate.

Electrode Preparation: Prepare the electrode plates by cleaning and polishing them to remove any contaminants or oxide layers. This ensures optimal contact between the electrodes and the electrolyte.

Cell Assembly: Assemble the multiplate Electrolyser cell by stacking the electrode plates with spacers in between. The spacers maintain uniform spacing between the plates to allow the even distribution of the electrolyte and promote efficient gas separation.

Electrical Connections: Connect the electrode plates in a series or parallel configuration, depending on the desired operating conditions. Series connection increases the operating voltage, while parallel connection increases the current capacity.

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Electrolyte Filling: Fill the electrolyte solution into the cell, ensuring that all electrode plates and spacers are immersed. The electrolyte should cover the entire active surface area of the electrodes.

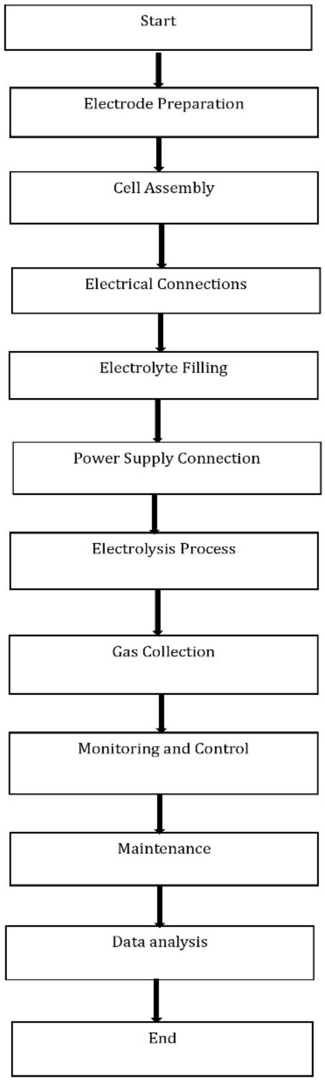

FIG 1 Flowchart of Methodology

Power Supply: Connect a DC power supply to the electrodes, applying a suitable voltage depending on the electrolyte and electrode materials. The positive terminal (anode) connects to the oxygen-evolving electrode, and the negative terminal (cathode) connects to the hydrogen-evolving electrode.

Electrolysis Process: When the power supply is turned on, electrolysis begins. The electric current causes water molecules at the cathode to undergo reduction, producing hydrogen gas (H2), while at the anode, oxidation of water molecules generates oxygen gas (O2).

Gas Collection: Separate and collect the hydrogen and oxygen gases evolved at the respective electrodes using gas collection systems such as bubblers or gas bags. Safety precautions should be taken when handling hydrogen gas due to its flammability.

Monitoring and Control: Monitor the operating parameters, such as current, voltage, temperature, and gas production rates. Adjust the power supply and control systems to optimize the efficiency and stability of the Electrolyser.

Maintenance and Safety: Regularly inspect and clean the Electrolyser to remove any deposits or impurities that may affect its performance. Follow safety guidelines and protocols when handling chemicals, electrical equipment, and gas collection.

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It's important to note that the specific methodology and parameters may vary depending on the design and configuration of the electrolyser, as well as the intended application and scale of operation.

Electrolysis plate surface are is very important factor for electrolysis that can design by thickness, material, width, length of plate and material composition of electrolysis plate.

11.1 MATERIAL SELECTION

Material selection

Sr no.	Part	Specification	Quantity
1	Electrolysis plates	Stainless Steel L310 Grade	43
2	Electrode	Stainless Steel L310 Grade	4
3	Dryer	TO Remove The Moisture	2
4	NRV Valve	Preventing The Backflow Of the Gas.	8
5	MQ08 and M135 Sensor	Hydrogen detection	2
6	Electrolysis tank	Polyeropylene	2
7	Hydrogen storage tank	high-pressure tanks	1

Fig 02: - Material selection Chart.

11.2 SYSTEM BLOCK DIAGRAM

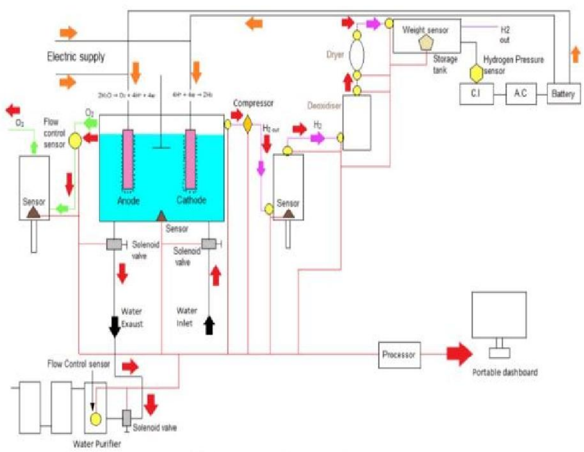

Fig.Hydrogen generation using electrolysis process

Fig 03; Hydrogen electrolyser Block Diagram

11.3 ELECTROLYSER

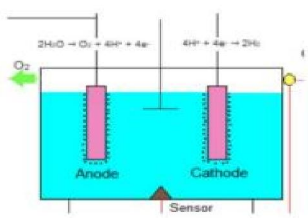

Fig 04 :- Electrolyser flow diagram.

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Like fuel cells, electrolysers consist of an anode and a cathode separated by an electrolyte. Water reacts at the anode to form oxygen and positively charged hydrogen ions (protons). The electrons flow through an external circuit and the hydrogen ions selectively move across the electrolyte to the cathode. At the cathode, hydrogen ions combine with electrons from the external circuit to form hydrogen gas.

Anode Reaction: 2H20 ➔ 02 + 4H+ + 4e

Cathode Reaction: 4H+ + 4e- ➔ 2H2

In that electrolyser basically known as the electrode that can help to do electrolysis its component is electrolysis plate, electrode Rod, input electricity wire node. Its are made up by stainless steel 310L grade that electrode cell is assemble in electrolysis tank

11.4 WATER FLOW INLET OUTLET

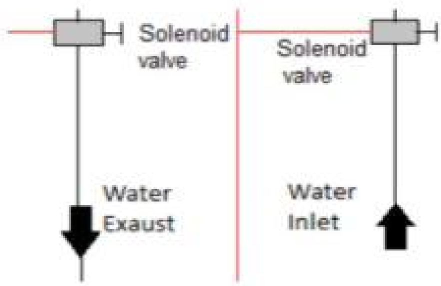
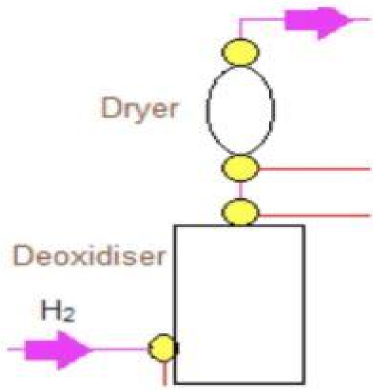


Fig 05:- water flow inlet outlet

In electrolysis process the main thing is required that is water. For electrolysis process it give the direct water inlet to electrolysis tank and also for removing water given the water outlet. for controlling the water inlet and outlet can use solenoid valves.

11.5 DEOXIDISER AND DRYER



To obtain pure and impurity-free hydrogen, a deoxidizer and dryer are utilized. The deoxidizer eliminates oxygen from the hydrogen, while the dryer transforms wet hydrogen into dry hydrogen. The dryer is employed to ensure the hydrogen is completely dry.

11.6 REGENRATIVE SYSTEM WITH STORAGE TANK

For storing hydrogen designed storage tank. Using weight sensor it able to measure the quantity of hydrogen in the tank. And also using sensors that can identify the leakages in the storage tank.

In Regenerative sytem, proposed System regenerate the electricity using the hydrogen. it can run the LC engine using hydrogen and using regeneration system we And that electricity stored into battery for commercial Purpose

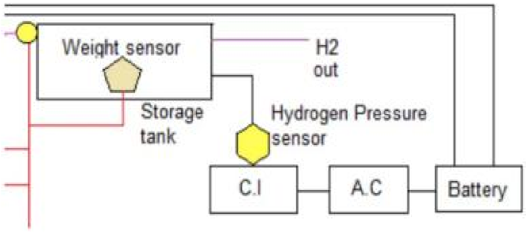


Fig 06 :- Hydrogen Concentration Detected By Hydrogen sensor

H2 generation Readings			
Energy	unit	H2 generation	unit
108.5	Watt	100	gm
542.5	Watt	500	gm
813.7	Watt	750	gm
1085	Watt	1000	gm

Chart 01 :- Hydrogen generation Reading For understanding concentration

With the help of control panel found hydrogen concentricity and actually hydrogen generation started or not also confirm following chart shows that input energy that system can generate 100gm hydrogen by consuming 108.5Watt energy means basically 1085watt energy requires to generate 1000gm Hydrogen.

```
H2 Concentration:26671ppm
H2 Concentration:4408ppm
H2 Concentration:14899ppm
H2 Concentration:6257ppm
H2 Concentration:4407ppm
H2 Concentration:3120ppm
H2 Concentration:2179ppm
H2 Concentration:1791ppm
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Fig 07:- Hydrogen Concentration Detected By Hydrogen sensor

Following output of control monitor system which shows the hydrogen concentricity at starting phase of electrolysis like 5000PPM To 150000PPM its shows concentricity of hydrogen and the identified hydrogen by the H2 detector sensor .

Fig -08: Actual Setup of Efficient Hydrogen Electrolysis System

Given image is a actual setup of efficient hydrogen electrolysis system with two electrolyser and storage tank of hydrogen with monitoring System .

XII. CONSTRUCTION OF SYSTEM

Multi plate electrolysis system developed on principle of maximum surface contact of electrolyser plate in water contact that can achieve maximum electrolysis In that case it has 2 electrode which material is stainless steel 310L grade that rod connected to plates center Two holes that electrode had 2 nodes for anode and cathode positive negative energy input connections that electrolysis cell are assembled vertically and they are kept in electrolysis tank

Input water are coming from filtered system it can take a pure input water for electrolysis. From inlet port. At outlet of electrolyser it can discharge the hydrogen and that hydrogen goes in dryer for removing the water molecules from hydrogen then it goes in dehumidifier then dehumidifier canremove the humidity from hydrogen and makes pure and dry hydrogen for better combustion or getting better output from pure efficient hydrogen.

That generated pure and dry hydrogen detected by the system for identify the hydrogen molecule and that detector can also found the concentration of hydrogen in (PPM) THAT System has a customize storage tank that storage tank can designed for customize requirement of system and the full fill the requirement of the system for gives the better output and also it can make a efficient storage tank that storage tank can help to improve the efficiency and it helps th handling the hydrogen. Hydrogen detection sensor connected before storage tank for detection of hydrogen and it identify hydrogen gives output on the monitor that can help to understand generation rate of hydrogen and all things related to hydrogen that also recognize the purity of hydrogen and its could be most important to understand the hydrogen generation system then finally connected the regenerative system for energy regeneration that can store the 30% energy from energy conservation also remaining hydrogen used to industrial purpose or any commercial purpose that so interesting.

XIII. WORKING OF THE SYSTEM

Step 1: The electrolysis system consists of two immersed electrolyzers in water. The electrodes are typically made of conductive material, such as stainless steel (L310 Grade).

Step 2: HH+ hydrocarbons are added to the electrolyte to enhance water conductivity.

Step 3: The two electrodes, known as the cathode and the anode, are connected to the negative and positive terminals of a DC power source, respectively.

Step 4: When the power supply is activated, a direct current (DC) is applied to the electrodes. Positive ions (H^+) from the electrolyte are attracted to the cathode, while negative ions (OH^-) are attracted to the anode.

Step 5: Hydrogen gas is produced at the cathode. The electrons received from the power source combine with positive ions to form hydrogen gas ($2H^+ + 2e^- \rightarrow H_2$).

Step 6: Oxygen gas is produced at the anode. The electrons received from the power source combine with negative ions to form oxygen gas ($4OH^- \rightarrow 2H_2O + O_2 + 4e^-$).

Step 7: As hydrogen and oxygen gases are generated, they rise to the top of the electrolyzer due to their lower density compared to water. Separate outlets are provided for collecting hydrogen and oxygen gases.

Step 8: Safety precautions are necessary due to the highly flammable nature of hydrogen gas to prevent any risks of explosion or fire.

XIV. BENEFITS OF THE EFFICIENT HYDROGEN ELECTROLYZER

It can generate hydrogen from a minimal amount of water, such as 1.4 gallons, while consuming minimal energy, making it highly efficient.

It offers cost-effective hydrogen generation, eliminating the need for significant investment.

The time required for generating 1 kg of hydrogen is reduced compared to existing systems.

The electrolysis process for producing 1 kg of hydrogen takes approximately 9 hours and consumes 1085 watts of energy.

XV. CALCULATION AND RESULTS

Calculations -:

Length of plate = 43 mm

Width of plate = 43mm

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Thickness of plate = 6 mm
Diameter of rod = 6 mm
Voltage = 12 V
Current = 90.5 A
Given material is steel 310L grade
From Ohm's law,
We find the resistance of a plate
R= V/I.
Where ' R 'is the resistance, I is current & V is Voltage
R= 2/90.5
R = 0.13259 Ω

Area of plate = $(\text{side})^2$
= $(43)^2$
Area = 1849 mm
Area = 18.49 cm
For finding conductivity the equation is
C= I/R.A
Where C = Conductivity, I = Current, A= Area, R=Resistance
C= 30.5/(0.13259 x 1849)
C = 0.3707
Weight of 1 Plate = 37 gm
Total no. of Plate = 30
Total Weight of all Plates = 1110
Number of Rods = 4
Weight of 1 Rod = 15 gm
Weight of all Rods = 60 gm
Total Weight of Rods and Plates = 1170 gm

Quantitative electrolysis = I = Q/T
90.5 = Q/(60 x 60) in sec
Q = 90.5 x (60 x 60)
Q = 3,25,800 c/s

1 L of water electrolysis = 237 KJ electrical energy
1 E = 96300 C

XVI CHEMICAL REACTION AND RESULTS

Anode Reaction: 2H2O ➔ O2 + 4H+ + 4e-
Cathode Reaction: 4H+ + 4e- ➔ 2H2
At the anode electrode, oxidation occurs, resulting in the production of oxygen from the positive (+) node.
At the cathode electrode, reduction of ions takes place, leading to the generation of hydrogen from the negative (-) node.

XVII. CONCLUSIONS

Based on this research, we have concluded that hydrogen generation using a multi-plate electrolyzer obtains its energy from renewable sources. It requires a certain amount of energy from the main source. This method of energy production is environmentally friendly and has various applications in commercial zones and for commercial purposes. It can be used to generate different types of non-conventional hydrogen, such as black hydrogen, pink hydrogen, green hydrogen, yellow hydrogen, and brown hydrogen.

XVIII. ACKNOWLEDGEMENT

It is our proud privilege and duty to acknowledge the kind of help and guidance received from several people in preparation of this report. It would not have been possible to prepare this report in this form without their valuable help, co-operation and guidance.

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