Production of Green Hydrogen from Electrolysis by using Solar Energy

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***Abstract*— The growing demand for cleaner and more sustainable energy sources has boosted the interest in green hydrogen production as this is a promising solution for decarbonizing various sectors. In this review, we will investigate the integration of solar photovoltaic (PV) technology with advanced electrolysis processes, creating a streamlined pathway to generate and exploit green hydrogen in an efficient way, high and environmentally friendly. By leveraging the collaboration between these two clean advances, our essential objective is to decrease green gas emissions, that will certainly diminish our dependence on fossil powers, and advance a greener and more economical future.**

***Index Terms*— Solar photovoltaic (PV), Green Hydrogen, Water electrolysis.**

I. INTRODUCTION

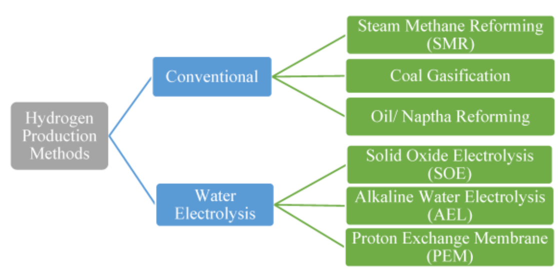
Hydrogen is the foremost copious component within the universe; it is show in 75 % of matter. It is utilized within the oil refining, the generation of smelling salts and methanol and the fabricating of steel. Right now, worldwide request for hydrogen is more than 70 million tons per year. The demand for hydrogen, which has multiplied by more than three since 1975 and it continues to increase. It is the fuel that will replace conventional fuels in future. Hydrogen contains more energy than natural gas, with clean combustion. It produces only water vapor as product hence, it is pollution free fuel.

Hydrogen is mainly classified as grey, blue, and green hydrogen by the processes used for manufacturing it. Grey hydrogen is produced by steam methane reforming (SMR) and other fossil fuel-based processes, such as coal gasification. The production of grey hydrogen results in significant carbon dioxide (CO2) emissions, as 50% of world's hydrogen is produced by steam methane reforming (SMR) process. Blue hydrogen is also produced by the SMR or different fossil fuel-based processes, but in this form, carbon capture and garage (CCS) technology is used to capture and store the CO2 emissions. The saved carbon dioxide isn't always launched into the environment. The use of CCS reduces its carbon footprint as compared to grey hydrogen. Green hydrogen is produced by water electrolysis, where electricity from renewable energy sources such as solar, wind, or hydropower is used for water electrolysis to split water into hydrogen and oxygen. Green hydrogen is produced without carbon emissions, as the energy source used is completely renewable.

Solar-powered hydrogen is in line with worldwide supportability objectives as sketched out within the Paris Understanding. Without any carbon neutralization technology, the members of the Paris Agreement are focusing on reducing greenhouse gas emissions to stabilize the amount of carbon dioxide in the atmosphere. To make a change and achieve net zero emissions, hydrogen will have to be produced by water splitting from renewable energy.

II. HYDROGEN PRODUCTION METHODS

Hydrogen production methods are classified as conventional methods and methods based on water electrolysis.



There are some methods from that hydrogen is produced by using the thermal decomposition of water based on renewable energy sources, such as solar energy, wind energy, geothermal energy, biomass energy, hydro energy, ocean thermal energy, tidal and wave energy, and nuclear radiation. Also, there are some other methods than water electrolysis for production of green hydrogen from renewable sources are biomass gasification, geothermal electrolysis, photoelectrochemical water splitting, hydroelectric electrolysis.

In this study, we are focusing on methods based on water electrolysis and which are using solar energy for production of water electrolysis.

III. HISTORY OF WATER ELECTROYSIS

The primary show of water electrolysis was made in 1789 by Dutch shipper Jan Rudolph Deiman, with the assistance of an electrostatic generator, in which an electrostatic release was delivered between two gold cathodes submerged in water. Afterward, Johann Wilhelm Ritter took advantage of Volta's battery innovation and isolated the item gasses. In 1888, the Russian build Dmitriy Lachi-nov created a mechanical blend strategy of hydrogen and oxygen through electrolysis. Early electrolysers utilized aqueous alkali arrangements as electrolytes, which is still within the use today. The foremost later improvement within the field of water electrolysis could be a handle called proton trade film (PEM) which was to begin with portrayed by Common Electric within the mid-1960s to deliver power for the Gemini space program, and afterward adjusted to electrolysis.

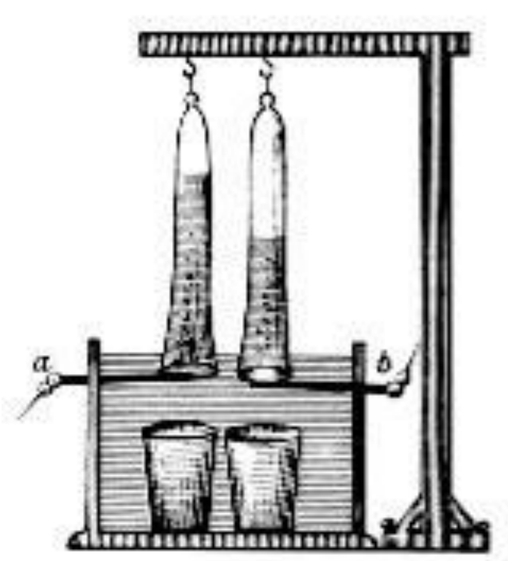


Fig. 1 Ritter Wasser electrolyze.

IV. WATER ELECROLYSIS

Water electrolysis is the method in which, water is part into hydrogen and oxygen through the application of electrical vitality. Regularly, a water electrolysis unit comprises of an anode, a cathode isolated with an electrolyte, and a control supply. Cathode anode pulls in emphatically charged particles (cations) from the water, which in this case are hydrogen particles (H+). Anode electrode attracts negatively charged ions (anions) from the water, which are hydroxide ions (OH-). These electrodes were then immersed in water. When the AC power is connected to the electrolyte arrangement, it drives the electrolysis process.

At the cathode, hydrogen particles (H+) pick up electrons (e-) from the electrical current and are decreased to create hydrogen gas (H2):

$$2H^+ + 2e^- \rightarrow H_2$$

At the anode, hydroxide ions (OH-) lose electrons and are oxidized to produce oxygen gas (O2):

$$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$$

The general reaction for the water electrolysis is:

$$H_2O + \text{electricity} \rightarrow H_2 + \tfrac{1}{2} O_2$$

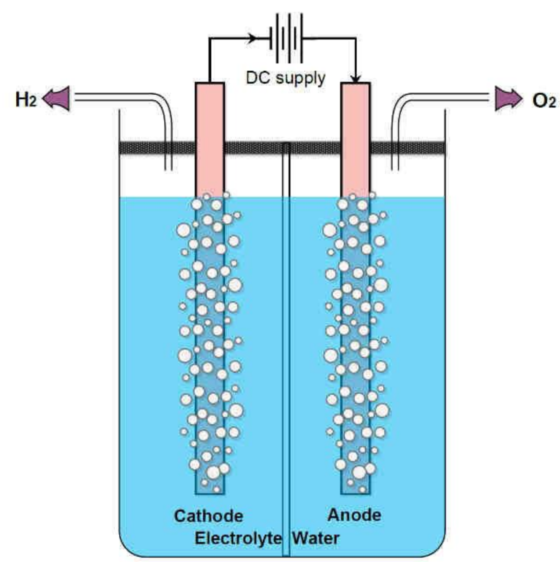


Fig. 2 Water Electrolysis

Green hydrogen may be a sort of hydrogen created through a handle called electrolysis, utilizing renewable vitality sources such as sun powered or wind control. It is considered as “green” because its production does not emit greenhouse gases. Methods for water electrolysis are as follows:

1) Alkaline water electrolysis.
2) Proton exchange membrane electrolysis.
3) Solid oxide water electrolysis.

V. ALKALINE WATER ELECTROLYSIS

Alkaline water electrolysis may be a strategy for creating hydrogen gas and oxygen gas through the electrochemical splitting of water. It is one of the foremost common strategies utilized for large-scale generation of hydrogen. Fig. 3 shows the process of alkaline water electrolysis. The most portion of soluble water electrolysis is the electrolysis cell, which comprises of two cathodes, an anode and a cathode, where they are drenched in a watery soluble electrolyte arrangement, for the most part potassium hydroxide (KOH) or sodium hydroxide (NaOH).

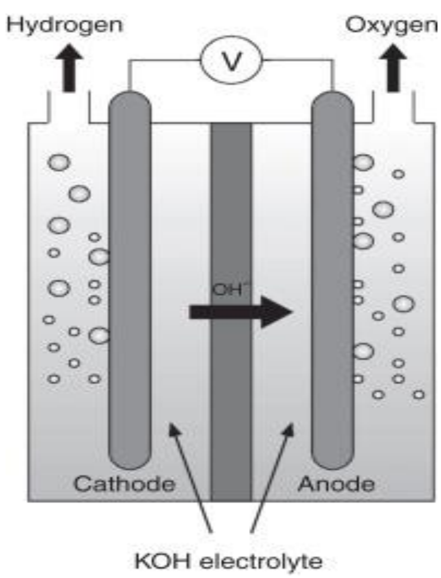


Fig. 3 Alkaline water electrolysis

When an electric current is connected to the cell, electrochemical responses happen same as responses depicted over in water electrolysis, and hydrogen gets created. Antacid water electrolysis is known for its tall proficiency, ordinarily extending from 70% to 80%. This electrolysis may be a attainable strategy for creating hydrogen gas from water and is broadly utilized in mechanical applications where huge amounts of high-purity hydrogen are required.

VI. PROTON EXCHANGE MEMBRANE ELECROLYSIS

Proton exchange membrane (PEM) electrolysis is an advanced method for producing hydrogen gas from water. It differs from alkaline water electrolysis in the type of electrolyte and design of the electrolysis cell. In PEM electrolysis, the electrolysis cell consists of electrodes, which are separated by a solid proton exchange membrane. This layer permits the section of protons H+ whereas blocking the entry of electrons and gasses. When an electric current is connected to the cell, two fundamental electrochemical responses happen at the same time at the anodes.

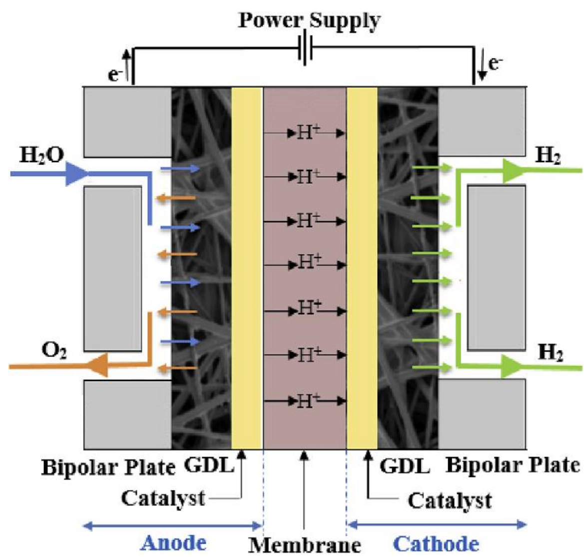


Fig. 4 Proton Exchange membrane electrolysis

Hydrogen gas and oxygen gas are generated at the respective electrodes. Fig. 4 shows the process of Proton exchange membrane electrolysis. The proton exchange membrane prevents gas mixing. PEM electrolysis offers tall vitality proficiency, ordinarily within the run of 75% to 85%. This tall proficiency makes it reasonable for different applications, counting hydrogen generation for fuel cells and vitality capacity.

Proton trade film electrolysis is a progressed and proficient strategy for creating high-purity hydrogen from water. Its tall effectiveness and fast reaction make it appropriate for a run of applications, particularly those requiring clean and productive hydrogen generation, such as fuel cell innovation and vitality capacity frameworks. Progressing investigate points to decrease costs and make strides the execution of PEM electrolysis innovation.

VII. SOLID OXIDE ELECTROLYSIS

Strong oxide electrolysis could be a high-temperature electrolysis innovation utilized to create hydrogen gas from water. It works at lifted temperatures and utilizes strong oxide materials as electrolyte. The strong oxide electrolysis cell comprises of an anode, a cathode, and a strong oxide electrolyte. These components are stacked together to make the electrolysis cell as appeared within the figure underneath.

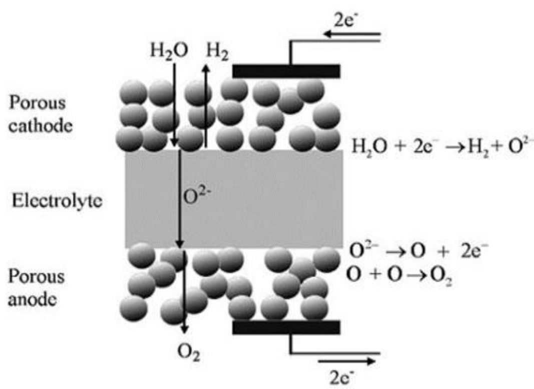


Fig. 5 Solid oxide electrolysis

Strong oxide electrolysis works at tall temperatures extending from 500°C to 1000°C. At such tall temperatures, water particles separate into protons (H+) and oxygen particles (O2-) near the strong oxide electrolyte. Fig. 5 shows the process of Solid oxide electrolysis. Strong oxide electrolysis offers tall vitality effectiveness, regularly around 80%. The tall temperature permits for productive separation of water atoms. It is commonly utilized in high-temperature mechanical forms and as a implies of vitality capacity when overabundance power is accessible.

VIII. ADVANTAGES

Alkaline water electrolysis: This type of electrolysis yields high purity hydrogen. It is simple in design. It is cost efficient for hydrogen production as requires low cost. As materials used in construction of electrolyser are low in cost, it is widely used in industry for hydrogen production.

Proton exchange membrane electrolysis: It is highly efficient electrolysis. It is compact in design and available in different sizes. Also have fast response. It can be easily integrated with renewable energy sources like solar and wind energy. It doesn't emit any greenhouse gases, so it is a clean and environmentally friendly process.

Solid oxide electrolysis: It operates at high temperatures; it results in more effective hydrogen production than low temperature electrolysis processes. It is integrated with high temperature industrial processes. It requires low capital cost. It can produce highly pure hydrogen. It is used for long time span. It is used as a fuel cell.

IX. DISADVANTAGES

Alkaline water electrolysis: It has low ionic conductivity. It requires a significant amount of electricity to operate. Its membrane has low stability and low lifetime.

Proton exchange membrane electrolysis: PEM electrolyser is expensive also its membrane is high in cost. Its membrane has low durability.

Solid oxide electrolysis: It is complex in design. The cost of the system is high as components used are costly. Its electrodes are unstable. It has safety and sealing problems. Material used in it is brittle.

X. RESULT AND DISCUSSION

Factors	Alkaline	PEM	Solid oxide
Efficiencies	70-80%	65-80%	80-90%
Power consumption (KWh/Nm^3)	4.1-4.3	4.5-7.5	3.5-4.5
Water consumption (L)	9	9	9

XI. FUTURE USE

Hydrogen produced from solar energy can be used as energy storage. Excess solar electricity can be used to produce hydrogen during periods of peak solar activity and then converted back into electricity via fuel cells when needed. Solar energy reduces dependency on fossil fuels. By using solar energy to produce hydrogen, we can ensure a sustainable supply of hydrogen for applications like transportation, infrastructure, and energy storage. The transportation sector is a major contributor to greenhouse gas emissions.

Green hydrogen can be used as a clean fuel for a vehicle including fuel cell electric vehicles. It offers long-range and fast refueling, making it a suitable alternative to fossil fuel. Green hydrogen can decarbonize industrial processes, particularly in sectors where high-temperature heat and chemical processes are essential. It can be used in the production of steel, cement, chemicals, and other materials, reducing carbon emissions. Hydrogen can be used in gas turbines or fuel cells to generate electricity and it will be supplied through to use domestically or commercially. It provides a means of storing excess renewable energy and can be used for grid balancing, especially in regions with high renewable energy penetration. Green hydrogen can serve as a large-scale energy storage solution. Excess renewable energy can be converted into hydrogen during periods of surplus and then converted back into electricity when needed. Green hydrogen can be used to produce fertilizers and to power fuel cell tractors and agricultural machinery, reducing emissions in the agriculture sector. It can be used in fuel cells to power ships and aircraft. Green hydrogen can be used in CCU processes, where captured carbon dioxide (CO2) is converted into valuable products, such as synthetic fuels or chemicals. Green hydrogen can be produced in regions with abundant renewable energy resources and exported to other regions as a clean energy carrier, contributing to international energy trade.

XII. CONCLUSION

The increasing worldwide demand for clean and sustainable energy solutions has led every country to grow interest in the production of green hydrogen. In this review paper, by the integration of solar photovoltaic technology with advanced electrolysis processes, we are offering a practical, and environmentally friendly approach for generating green hydrogen. By combining the potential of these clean technologies, our research aims to reduce greenhouse gas emissions, and taking a step forward toward eliminating and lessening our dependency on fossil fuels, and to find the way towards a greener, and more sustainable future.

The green hydrogen produced by renewable energy driven electrolysis can give a clean and zero emission energy carrier. The method of electrolysis includes alkaline water electrolysis, proton exchange membrane (PEM) electrolysis, and solid oxide water electrolysis. Each of these methods offers a unique advantage and provides high energy efficiency that are essential contributors for the evolving landscape of renewable energy.

Also, the potential for solar-powered hydrogen serves as a means of energy storage that offers a sustainable solution for the irregularity of renewable energy sources. This transformative approach reduces dependence on conventional fossil fuels and can contribute significantly to decarbonizing sectors like transportation. When effectively utilized solar-generated hydrogen, it has a high efficiency and can offers a cleaner and more sustainable fuel source for more environmentally friendly future.

XIII. REFERENCES

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