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HYDROGEN BASED SYSTEMS FOR INTEGRATION OF RENEWABLE ENERGY IN POWER SYSTEM

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Abstract: Interest in green hydrogen is growing with researchers, organizations and countries focus on developing hydrogen as energy source, increasing efficiency and reduction of costs. This thesis examines the concept of green hydrogen and renewable energy production systems in India. This area has great potential for the production of green hydrogen, which promotes the transition from fossil fuels to clean energy and supports environmental sustainability through the electrolysis process. The paper also explores the benefits of green hydrogen as an alternative to fossil fuels and highlights the environmental benefits of zero net greenhouse gas emissions. It is also exploring the benefits of using green hydrogen in various industries, business and transportation. Research shows that when used correctly in the right applications, improving production and storage technology and increasing efficiency is good in many areas, and green hydrogen can be the fuel of the future. Optimization strategies can be used to maximize efficiency, reduce costs, and reduce environmental impacts in the design and operation of green energy systems. International collaboration and cooperation are essential to develop this technology and realize its full benefits. Hydrogen has become an important factor in the integration and development of renewable energy sources (RES) into today's energy systems. It plays an important role as an energy storage system (ESS), ensuring the stability and reliability of the grid. Due to its high energy density, large storage capacity, and high operating speed, hydrogen is rapidly gaining popularity as the alternative energy storage of choice.

Keywords: Green Hydrogen, Renewable Energy, Clean Energy, Environmental Sustainability, Renewable Energy Sources (RES), Energy Storage System (ESS)

1. Introduction

1.1 Hydrogen Technology

Hydrogen energy technology offers a solution to the growing demand for sustainable energy systems. While the long-term challenge is the production of large amounts of hydrogen from renewable energy sources, the real problem is how to store hydrogen efficiently and safely, especially for hydrogen ambulances. Hydrogen can be stored physically or chemically. Traditional options for physical storage are compressed hydrogen and cryogenic adsorption, i.e. liquid hydrogen. For chemical storage, hydrogen molecules can split homolytically or heterolytically and combine with other elements to form hydrides. The absorption and release of hydrogen can be reversible or irreversible depending on the temperature of the initial and final products.

Hydrogens are of two types, green hydrogen & blue hydrogen. Green hydrogen, produced by splitting water using renewable energy, represents an efficient and environmentally friendly solution. Unlike gray hydrogen produced from fossil fuels, green hydrogen production does not emit carbon dioxide or other harmful gases. Although blue hydrogen is a step towards reducing emissions, it also causes emissions to the environment. Green hydrogen is used as a clean alternative in many areas, including power generation, public transportation, and the marine and aviation industries. Its adoption is important to promote environmental sustainability and reduce carbon emissions and is a significant step towards a greener future.

Hydrogen is the unadorned and most profuse element on Earth. It is necessary for water, oil, gas and all living things. Although hydrogen is simple and abundant, it is rare as a gas on Earth. It generally united with other elements. It can be produced from oil, gas and biomass, or from the splitting of water using renewable solar energy or electricity. When hydrogen gas is formed in the form of molecular hydrogen, the energy contained in the molecule is released and it reacts with oxygen to form water. This can be done by an internal generator or a device called a fuel cell. In the fuel cell, hydrogen energy is converted directly into electricity with high efficiency and without energy loss.

1.2. Hydrogen Energy System

Hydrogen energy system composed of production, transportation/storage of hydrogen. It consists of technologies for transporting and storing hydrogen with less energy are particularly important. At present, according to the transportation and storage medium of hydrogen, high pressure hydrogen, storage alloys, liquid hydrogen (LH2), composite materials, carbon species, etc. have been developed, but in fact all methods have been found to be inferior to energy conversion. from fossil fuels. Among them, the density of LH2 at high temperature is approximately 800 times greater than that of hydrogen, making it a hydrogen bond. Storage of hydrogen here will explain the data of gas and liquid hydrogen LH2. State-of-the-art technology in the development of high-pressure vessels for gas and liquid hydrogen storage

In the last decade of research and research, the diversity of candidate hydrogen storage materials has expanded from conventional metal hydrides such as LaNi5 and MgH2 to activated carbon mixed hydrides and chemical hydrides to carbon nanotubes. and metal-organic frameworks (MOFs). The adoption of advanced bonding techniques also changes the physical properties of storage materials from bulk crystals to amorphous and nanostructures. Advanced theoretical simulations are having an increasing impact not only in physically describing known data but also in predicting new models and reaction mechanisms. Many promising multisystem are under intensive investigation. High hydrogen contents are the focus of ongoing research because they provide many opportunities for modification and optimization.

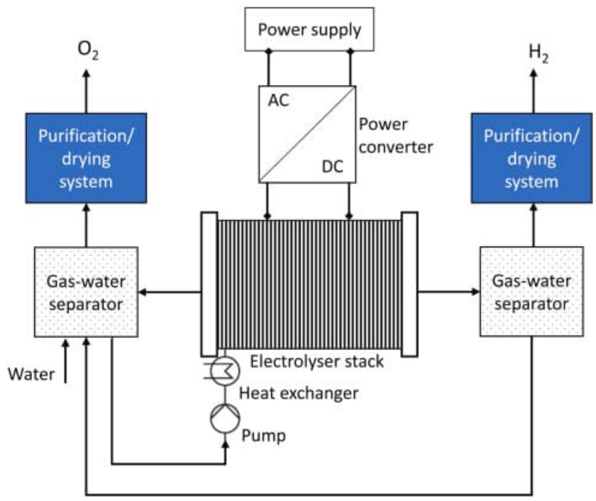

Figure 1 : Hydrogen Energy System

1.3 Role of Renewable Energy & its Sources in Sustainable Development

Sustainable development for a better future for all, economic, social and environmental balance. The goal where everyone has access to theresources, they need to live a good life without harming the environment.

the most important ways renewable energy technology contributes to sustainability.

1. Reduce greenhouse gas emissions: By using renewable energy, greenhouse gas emissions will be reduced and the impact of climate change can be reduced. With clean, renewable energy sources such as solar and wind energy, the use of fossil fuels and the environmental damage caused by carbon dioxide emissions can be reduced. This sustainable growth will help the Indian financial sector achieve phenomenal growth.

2. Additional energy security: Renewable energy can contribute to energy security by reducing electricity demand and increasing the reliability of electrical equipment. By using key resources such as solar and wind, the country can increase energy independence and reduce dependence on foreign energy sources. In today's world, renewable energy is energy that can be trusted. Oil diversification reduces the risk of oil spills and reduces the country's dependence on imported oil.

3. Provide energy: Particularly in poor countries, previously vulnerable groups now have access to renewable energy. Although access to energy is essential for many aspects of daily life, such as lighting, cooking and heating, it can also reduce hunger and improve lifestyle. The Indian government has initiated various measures to provide electricity to all regions. Renewable energy investments have made energy more accessible, benefiting people across the country and even in remote areas.

4. Promoting the development of ruralpeople :Renewable energy technology can contribute to the development of people in rural areas through agricultural productivity by providing power to the rural population, promote economic growth and improve the quality of life. It is important to consider how our environment is affected by everything within it. Protecting the environment and natural resources is everyone's responsibility. In recent years, the uncontrolled use of non-renewable materials has caused serious climate change. Therefore, the use of renewable energy will help reduce climate change and ensure sustainability for future generations.

5. Job Creation Prospects: Renewable energy technologies have the potential to contribute to business expansion and employment creation, especially in the production and installation of new renewable energy systems. For example, the expansion of the solar industry has created many jobs in solar panel manufacturing and installation.

2. Literature Review

2.1 Green Hydrogen Energy Revolution in India

Green hydrogen production: India is focusing on renewable energy and has set a target of 450 GW of renewable energy capacity by 2030. Production laid a solid foundation. The government announced the National Hydrogen Mission to increase hydrogen production and promote its use in various projects.

Transportation: India is exploring the use of green hydrogen in transportation. The government plans to develop hydrogen fuel infrastructure and promote the use of hydrogen vehicles. The measures include the production of hydrogen-powered buses, cars and two-wheelers, as well as the installation of hydrogen stations.

Industrial Applications: In India, industries such as steel, cement and chemicals are exploring the use of green hydrogen to decarbonise their operations. Green hydrogen can be used in industry as a reducing agent or heat source to replace fossil fuels. This change could reduce greenhouse gas emissions from these activities

Hydrogen solutions can transform the global energy system from fossil fuels to low-carbon and ultimately zero-carbon. This generator is the main source of energy for hard-to-mitigate industries such as heavy transportation and other emissions-intensive industries such as steelmaking. Chemistry holds the key to turning hydrogen into the green energy solution of the future. The green hydrogen revolution is becoming a reality with advanced equipment for hydrogen production, infrastructure and transportation. It is used in electrolyzers, fuel cells and other hydrogen systems. As the green hydrogen market accelerates, we will continue to work with our customers to make this happen.

Hydrogen was first developed in the 16th century, and the first fuel cells and electrolyzers were developed in the 19th century. But until recently, electrolyzers (which produce green hydrogen by using electricity to split water into hydrogen and oxygen) and fuel cells (which recombine electricity and air to produce heat) were too expensive. It's all changed. The cost of electrolyzers has increased from 200 euros per megawatt to 4 million euros a few years ago, and today to 500,000 euros. This means that the main driver of the cost of producing hydrogen from electricity is now electricity itself, accounting for a third of the cost of production.

As green electricity becomes cheaper, low-cost green hydrogen is also on the horizon. At the same time, like solar and wind, hydrogen prices are falling exponentially as system size, output and efficiency increase. One of the most polluting gases we have to work with is hydrogen - in our cars, buses, Cape injection plants, etc.

3. Working Methodology

3.1 Hydrogen Production methods

Historically, most commercial hydrogen production has come from fossil fuels, primarily natural gas, oil, and coal. This process is called steam methane reforming (SMR), partial oxidation, and coal gasification, respectively. These processes are called "gray hydrogen" or "brown hydrogen" because they release carbon dioxide (CO2) emissions during their production. Natural gas is the most common feedstock for hydrogen production, accounting for approximately 48% of global hydrogen production. A methane converter will cause carbon monoxide to react with air to produce hydrogen and carbon monoxide. The mixture, called syngas or synthesis gas, is then further processed to separate the hydrogen. Petroleum, including petroleum and petroleum products, is another source of hydrogen, accounting for approximately 30% of global production. Hydrogen can be obtained as a product of various refining processes such as catalytic reforming or hydrocracking.

Coal still accounts for about 18% of world hydrogen production, although less than natural gas and oil. Coal gasification is the process of converting coal into synthesis gas, which can then be processed to produce hydrogen. Electrolysis, a process that uses electricity to split water molecules into hydrogen and oxygen, accounts for about 4% of global hydrogen production. This method is called “green hydrogen” because it can be used by renewable energy sources such as solar or wind, resulting in zero direct carbon emissions. However, it is worth noting that these percentages may vary depending on specific times and regional conditions. In recent years, there has been interest in increasing the share of green hydrogen production based on electrolysis due to its carbon neutrality and sustainability potential.

3.2 Modelling of Hydrogen Storage Cell

Thermal management is necessary for safe and effective fuel cells. The aim of this article is to create an accurate fuel cell thermal control system controlled by algorithms. We first developed a control-oriented model for the thermal control system of the fuel cell stack. We then summarize the requirements for thermal management and formalize them using linear sequential logic. Standards and requirements are then used to manage connections through the abstract process. To make precision-based combination algorithms efficient, some models of fuel cell system dynamics need to be defined and implemented. Finally, the closed-loop system behaviour of the integrated controller is demonstrated through simulations. A fuel cell is an electronic device that converts the electrical energy of a fuel (e.g. hydrogen) into electricity. In a fuel cell stack, the electrochemical reaction of oxygen and hydrogen produces electricity, with heat and water as byproducts.

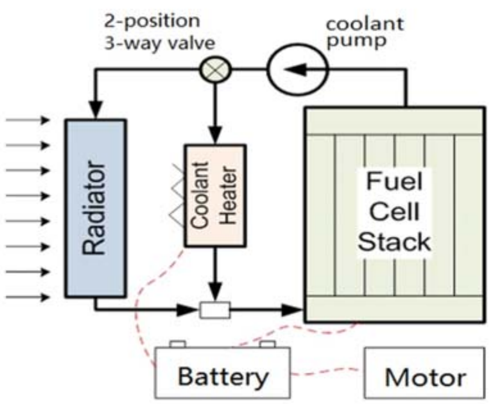

Figure 2 : Hydrogen Cell System's layout

A simple schematic of the fuel cell thermal control system is shown in above figure. While the coolant flow is controlled by the power pump, the coolant inlet temperature is adjusted by increasing the coolant flow from the radiator or heater where it flows. The two-position three-way valve is selected by the system so that it is already made. Dynamic hybrid. Power demand has a direct impact on thermal management, and some aspects of thermal management have been studied in. First, the power demand of the engine and the temperature of the fuel must be achieved simultaneously through a combination, for example, through appropriate power control of fuel cell stacks and electronic devices. Because the heat produced in the group increases with the fuel cells.

4. Result

4.1 Chemical Equation

The electrolysis of water is represented by the following chemical equation

2H2O(I) 2H2(g) + O2(g)……….………..(1)

This equation illustrates that two water molecules (H2O) are converted into two hydrogen molecules (H2) and one oxygen molecule (O2) during the electrolysis process. Electrolysis involves the use of an external electrical energy source, typically a direct-current (DC) power supply, to drive the oxidation of water at the anode and the reduction of water at the cathode.

The electrolysis process can be further described by the following half-reactions:

Anode: 2H2O(l) → O2(g) + 4H+(aq) + 4e……………………(2)

Cathode: 4H2O(l) + 4e 2H2(g) + 40H-(aq)…………………..(3)

By combining these half-reactions and canceling out the electrons, the overall reaction is obtained as follows:

$2H_2O(I)$ $2H_2(g)$ + $O_2(g)$………..………….(4)

The minimum energy required for this reaction can be calculated using the following CO tion:

E = AG/Nf………………..….(5)

where E is the applied voltage, AG is the Gibbs free energy change, n is the number of electrons transferred (four electrons in this case), and F is the Faraday constant. The Gibbs free energy change (AG) for the reaction is given by:

AG = -nFE°……………………(6)

The standard electrode potentials (E°) for the respective half-reactions are:

E°(H2O 1/202 + 2H+) = +1.23 V……………………(7)

E°(2H2O + 2e H2 + 2OH-) = -0.83 V……………………..(8)

Therefore, the overall standard electrode potential (E°) for the reaction is:

E° = E°(H2O→ 1/202 + 2H+) - E°(2H2O + 2e- H2 + 2OH-) = +2.06 V………………….(9)

Practically speaking, there are various techniques for performing the electrolysis of water, such as alkaline electrolysis, polymer electrolyte membrane (PEM) electrolysis, and solid oxide electrolysis. These techniques differ in their operating conditions, efficiency, and cost, and are utilized in different applications based on specific process requirements. For example, proton exchange membrane electrolysis is often used in small applications, while alkaline electrolysis is more common in large-scale industrial processes.

5. Future Aspects

India is focusing on renewable energy and has set a target of 450 GW of renewable energy capacity by 2030. Production laid a solid foundation. The government announced the National Hydrogen Mission to increase hydrogen production and promote its use in various projects.

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Conclusion

This research paper highlights the importance of green hydrogen in renewable and clean energy, highlighting its enormous potential to achieve global environmental goals and reduce emissions pollution. As an energy source, green hydrogen has many applications in industry, transportation, heating and cooling. It can be produced through a variety of processes, including the distillation of petroleum, coal mining, desalination of brackish water, and natural gas conversion. There is now growing interest worldwide in using renewable energy sources such as solar, wind and hydropower to produce green hydrogen. This variant is thought to be cleaner and more environmentally friendly than the blue and yellow hydrogen produced from natural gas and coal.Although there are challenges with production costs, storage, and transportation, significant efforts are being made to overcome the obstacles and facilitate increased production.By evaluating factors such as environmental impact assessment, technological progress, infrastructure, infrastructure, policy, business capability and workforce transformation, this article provides information to help unravel the complexity of integrating green hydrogen into the energy landscape. The full potential of green hydrogen, creating a cleaner and more sustainable energy future, can only be achieved through careful monitoring and collaboration.

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