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Review of Hydrogen-Based Energy Storage Techniques

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Abstract: Hydrogen is significant and may be viewed as an alternative for main fossil fuels, coal, crude oil, and natural gas, as well as its derivatives when utilized as fuel. It has the potential to be a clean, efficient, and inexpensive energy source. The main benefit is that its oxygen-burning products are water and not carbon-containing and greenhouse gases CO and CO_2. Conventional forms of energy are dependent on fossil fuels and have several consequences, namely pollution, climate change, and increased price. Promising alternatives are renewable energy sources like solar and wind energy. However, the main limitation for renewable energy sources is that they are always unavailable and provide us with interrupted energy. As a result, energy resources should be combined with energy storage devices in order to offer continuous power. This paper examines the various storage systems and concentrates on energy storage systems based on hydrogen.

Keywords: Fuel cell, Hydrogen, Hydrogen storage, Sustainable energy.

I. Introduction

The current mainstream energy source is fossil fuels that have enormous effects on the environment and climate change. Trace gas which contributes considerably to rising temperatures, oxides of sulphur and oxides of nitrogen causing acid rain and chemical contamination, do not simply produce carbon dioxide. Furthermore, during the next few years, fossil fuels will disappear. As a consequence of their sustainability and cost-effectiveness, much Intensively exploring renewable energy (RE) resources [1-6]. A few of the primary limitations of Renewable resources is that they provide us with discontinuous energy, most of them not available on a continuous basis. For example, the night and rainy days do not have solar energy. From time to time, the wind speed varies. Therefore, the need of constructing energy storage systems is increasing as power output from RE resources increases [7-9].

The electricity generation options include Battery Energy Storage Systems (BESS), Large - Scale Energy Storage (CAES) and Magnetic Superconducting Energy Storage (SMES), hydrostatic pumps and hydraulic fuel cells. The production of hydrogen is one of the latest solutions to store the excess energy produced during off-peak hours. The stored hydrogen can then be utilized not just as a fuel in hydrogen vehicles but for energy generation at the highest hours. Water electrolysis is the most often hydrogen manufacturing process, where hydrogen (O_2) and oxygen (O_2) molecules are examined by electrical means. H_2 and O_2 are mixed in the fuel cells to generate water (H_2O) and energy when RE sources is not available. This paper examines hydrogen energy storage systems and describes current hydrogen storage systems techniques. It also discusses the issues related to technology [10-12].

II. About Hydrogen Energy

By its collision with antimatter, the annihilation of the matter is the most powerful mass conversion per unit of energy envisaged, but beyond our reach. Fusion of helium of four atoms of such a light element creates large quantities of power, such as our sun intergalactic stars, utilize hydrogen extraordinarily energy efficient. A little proportion of the atom mass of hydrogen cannot be transformed into helium mass, and after the well-known Einsteinium equation, it is enough to generate a great many energies. Although nuclear fusion has been created and tried a long time ago, as a process for large-scale energy generation used by mankind, it is not practical, cheap, or up to date possible. While the energy generated by a fusion event is estimated at millions of eV, ionising energy is usual in order to shift the electron from a hydrogen atom. The chemical process is just 13.6 eV [13]. Although the nuclear fusion may eventually become possible, it will not occur soon. However, chemical and electrochemical reactions are available as realistic energy generation techniques. And that's not bad, that's not bad. It is excellent compared with ineffective 20^{th} century thermal machinery, which used multiple conversion stages to burn fossil fuels for the generation of energy. In this century, the energy-efficient direct and one-stop conversion to electric power and heat energy contained in the fuel using fuel piles is good for controlling energy picture [14].

Hydrogen energy is about the utilization of substances containing hydrogen and hydrogen to provide energy for all practical uses, with high energy efficiency, overwhelming environmental, social and economical advantages. The birth of the energy of

hydrogen revolutionises numerous elements of modern society, making it possible for energy to be produced and used circularly, making convenient and beneficial use of the vast quantity of waste resulting from an evolved way of life and decarbonizing the different sectors that consume intense energy, making it possible to implement broad renewable energy production [15]. From fossil fuel saving to hydrogen energy saving ; new techniques must be put in place as illustrated in Fig. 1.

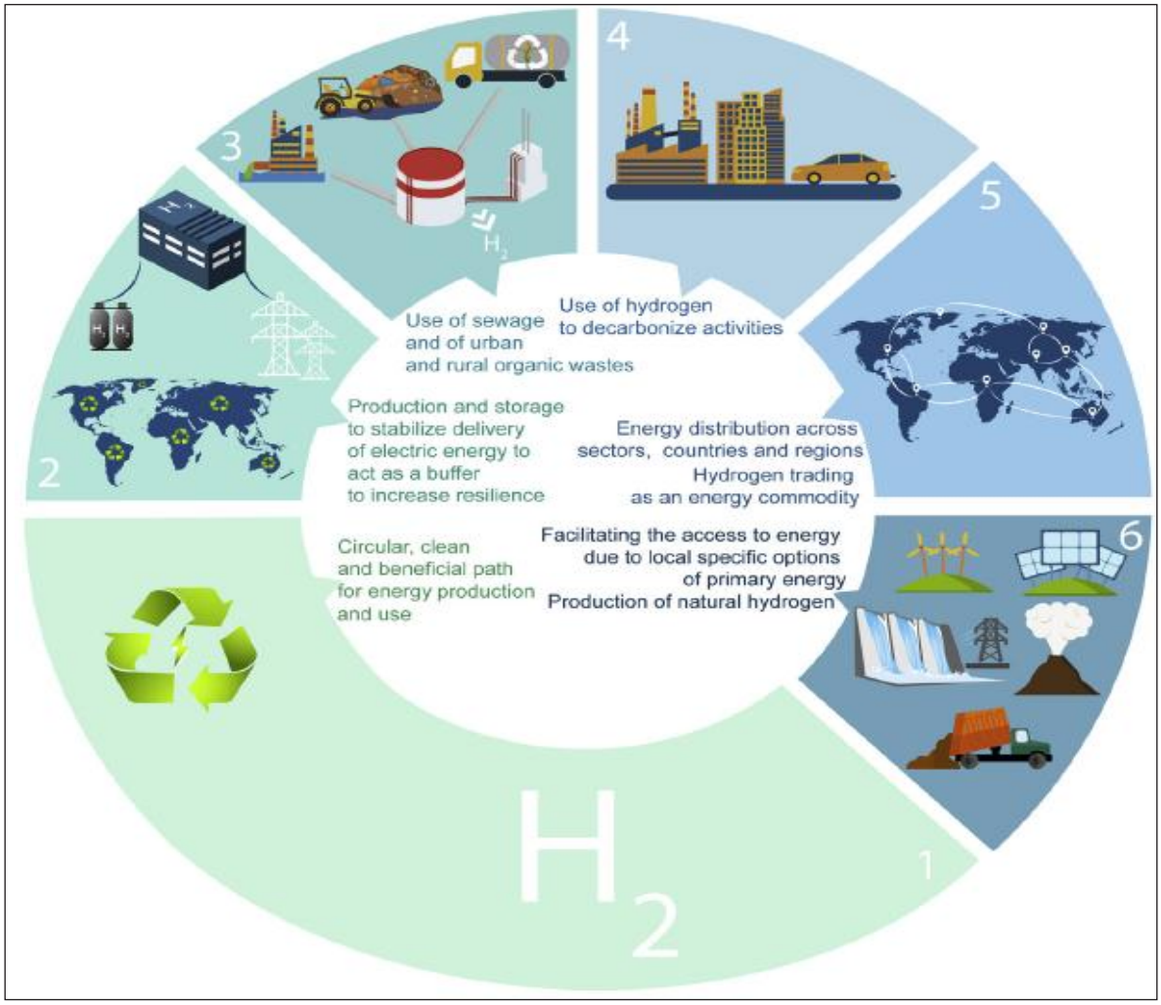

Fig. 1: The Different Features and Opportunities Relating to the Application of Hydrogen Energy Technology

These includes:

- Circular, clean and beneficial paths for the generation and use of energy.
- Broadly utilizing, including renewable energies.
  - Hydrogen generation and storage for electrical energy supply stabilization, which regulates the intrinsic intermittence of renewable resources.
  - Hydrogen production and storage function as a buffer to strengthen a country's or region's resilience.
- Use in water, urban and rural organic waste for the generation of hydrogen-rich fumes and compounds.
- Using hydrogen in fields such as the decarbonisation, electrical and thermal energy industry; delivery of biomass-produced sustainable feedstock through a convenient reaction to hydrogen.
- Spend energy on the hydrogen-gain gas and substance as carriers, governments, and territories and also the trading of hydrogen as a source of energy.
- Encouraging energy availability through local, particular options for primary energy resources as well as raw resources in different countries and areas for producing hydrogen and local natural hydrogen production.

When water electrolysis produces hydrogen and is used in cells for fuel, as a by-product, water resurfaces, which closes a circular cycle that is beneficial. The creation of such hydrogen is deemed when renewable energy sources are used as energy sources, it is environmentally favorable. This is facilitated in countries like Brazil. China, the United States, Canada, and others that produce a great deal of electrical energy from hydropower stations, with exaggerated turbines generating turbinate

wastewater in some periods of the year, due to difficulties with the storage of electricity once produced. In other words, if the demand for energy is reduced, either water is deposited in a water barrage that does not flow to the river or water fills the turbines. Instead, electricity created can be used as a means of storing energy for hydrogen generation. For the numerous energy or it is discovered in typical chemical operations, the hydrogen then created may be utilized [16]. In the same way, electrical energy from other renewable energy sources, such as ocean energy, wind power, solar may be used to generate water electrolyzes by hydrogen. In these instances, the creation of hydrogen by water electrolysis utilizing renewable energy sources offers two additional advantages. Firstly, hydrogen can be used to supplement and regulate electrical energy supply concerns relating to renewable energy generation intermittent. If the wind, water, ocean, and sun activity is inadequate but there is an electricity demand, the already generated and stored hydrogen is accessible to generate energy using fuel cells and/or turbines. The second advantage of hydrogen storage is that it can operate as a buffer to strengthen the resilience of a country or region's energy system in full, taking account of the entire renewable or not power generation process and thus stabilize a regional energy distribution network [17].

III. Use of Hydrogen

Hydrogen can be used in two superior ways:

- Internal Combustion/Fireworks Engine (ICE)
- Fuel Cell (FC)

As the fuel cells improve, ICE is likely to be a transitional technology since the changes the costs of converting an ICE to run on hydrogen aren't too high. The FC should however serve as the preferred hydrogen-fueled energy generator in the future because of its essentially emission-free, efficient, and dependable qualities [18].

A. Fuel Cell (FC)

The stored chemical energy in a fuel cell is transformed directly into electricity, in this example hydrogen. Two electrodes separated by an electrolyte are composed of a fuel cell (Fig. 2).

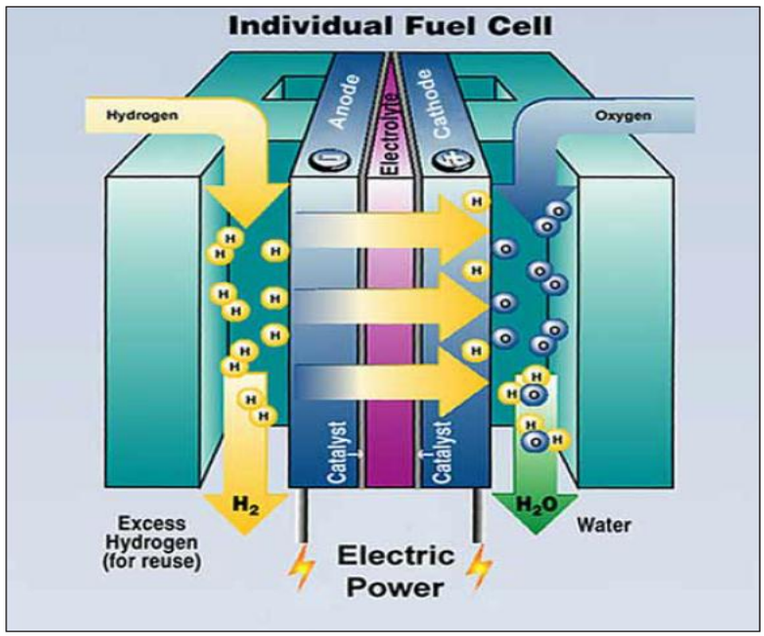

Fig. 2: Fuel Cell [30]

IV. Methods of Hydrogen-Based Energy Storage Currently in Use

Hydrogen utilization was tested and analyzed in recent years in energy storage devices. Each section presents the latest work in this area.

- It presented an Integrated Wind Energy storage system and a Combined Cycle Power Plant (CCPP) hydrogen-oxygen with energy performance from 0.49 to 0.55. You decided that it can be used in any geological condition and that the proposed storage system looks to be a reasonable solution for intermittent renewable energies. There was a study conducted that carried out on a 100 MW wind turbine, which produces 225 GWh per year of electricity in Jiangsu Province, China. Economic studies and energy efficiency suggest the suggested system can achieve an overall capacity of up to 0.50% and can compensate for unpredictable electricity production [19].
- A wind-hydrogen micro-grid technology was implemented in Fife, Scotland, simulated, and evaluated at TRIF.

The wind-hydrogen energy system has shown an average inaccuracy of under 0,02 for its dynamic behavior. The microgrid is connected to the grid with the power supply, comprising an electrical electrolyzer, a fuel cell and a hydrogen storage tank [20].

- It has theoretically and experimentally explored and compared hydrogen-based microgrid energy management strategies. This paper outlines the building of a microgrid system in a laboratory to mimic and analyze various energy management strategies in real life. The study contrasts simple strategies with complicated techniques of online optimization such as predictive control models. The output show how various control techniques may drastically affect performance of the system [21].
- A MATLAB technique for hydrogen resolution optimization in storage systems was developed. For the use of algorithms, they selected the Aegean Sea where various islands with diverse RE sources are accessible, including wind and sun energy. A temporary buffer storage unit, which stores hydrogen from water electrolysis and metal hydride tanks to store the hydrogen in the final form under low pressure, is modeled on an alkalized electrolyzer to analyze water into hydrogen and oxygen by means of electronic energy. The authors found that the methodology provided can give the hydrogen power storage system the optimum ability [22].
- Towards the Power to Gas (PtG) technology, it was examined electrical process requirements. PtG's energy generated from RE sources is utilized to analyze water to electrolyze hydrogen and oxygen. During the electrolysis, hydrogen is then produced as a synthetic natural gas in combination with Carbon Dioxide (CO_2) (SNG). For the operation of an oxy-combustion plant, the generated oxygen can be used. The evaluation was carried out on the basis of the size of the plant, the physiochemical characteristics of the fuel, and its end application. The authors indicated that district heating, industrial operations, and tiny CCPPs are the most suitable application of the PtG-Oxycombustion hybridization technique. The efficiency of the hybrid system has been successfully enhanced from 56% to 68% when the tiny CCPP is modeling and simulation and integration into the PtG process thermally. The scientists concluded that the gas hybridization process of Oxy-combustion uses fewer electrolytic systems than other network power plants. It can achieve greater net electricity efficiency and generate more heat than coal-fired power plants [23].

Table I: Provides a Summary of the above Approaches

Methods	*Summary*
[19]	Proposed an integrated wind and hydrogen-oxygen CCPP storage system.
[20]	The microgrid power wind-hydrogen system in Scotland was modelled, evaluated and assessed.
[21]	Energy management solutions in hydrogen micro-networks were theoretically and experimentally studied and compared.
[22]	A simulation tool has been developed for MATLAB to optimize hydrogen storage system sizing.
[23]	The electricity to gas process requirements for the production of methane as natural synthetic gas has been evaluated.

V. Disadvantages

The main drawback of hydrogen is the enormous losses resulting from the number of conversions. In the case of an energy-induced system, the following stages with related efficiencies typically have been undertaken when hydrogen is utilized for its final purpose:

- The electrolysis is generating hydrogen - efficient by 85%;
- storing of hydrogen - efficient by 65% to 70%;
- and hydrogen utilization in fuel-cell automobiles, power plants, and CHP devices - performance ranges from 40% to 80%.

The whole output thus amounts to between 22% and 48%. This technique also requires only one storage stage during hydrogen life, when more than one storage step, i.e. when made and stored on the site of usage, is normally needed. The hydrogen economy is therefore very efficient and could lead to high energy expenditures and very inefficient use of finite resources like wind or biomass. The efficiency of the system is relatively low. In short, although the hydrogen energy storage technology offers enormous flexibility, it does not contribute to the overall efficiency of the energy system [24-26].

VI. Future of Hydrogen Energy Storage System

With electrolyzes, storage techniques and fuel cells becoming more economically available the usage of hydrogen in the transport and energy-producing industries should be expanded fast.

Hydrogen programs, which show an expanding interest in hydrogen technology, are particularly ambitious in the EU, the United States, and Japan. By creating hydrogen from the excess renewable energy and transitioning its transport infrastructures from fossil fuels to hydrogen, Iceland is trying to become the first 'hydrogen country' in the world [27]. Statkraft wants to connect an electrolysis unit with a huge wind turbine in Norway, and Norsk Hydro is carrying out a wind system in Utsira Island. The wind hydrogen motor is being developed in Germany, Siemens, and P&T Technologies using an ICE. In Great Britain, Wind Hydrogen Limited plans to construct wind-hydrogen systems on a big scale. In California, Hy-Gen is also creating a network that produces and distributes multi-megawatt hydrogen. Automobile manufacturers are driving hydrogen development in the transportation and infrastructure sectors [28]. The automobile companies have developed a strategy for introducing hydrogen into transportation, which includes a number of solo prototype initiatives that will progress to fleet demonstration. Due to its adaptability, hydrogen is a serious supporter of future energy storage. Once hydrogen can be successfully produced, it can be used for virtually any desired application. The most desirable goal today is therefore to produce sustainable hydrogen via electrolysis. "The transition toward a hydrogen economy is expected to be less than 50 years away," mainly because of the versatility and potential of hydrogen to replace conventional fuel [29].

VII. Conclusion

The hydrogen energy storage system has become more and more a major challenger in the transport industry for power production. We have described the many ways to energy storage including hydrogen power generation. The latest hydrogen storage methods were summarized and the technological problems in this area were addressed. Hydrogen-based storage is a potential technique for the storage of energy. It is used for the conversion of hydrogen back to electricity, hydrogen is therefore apparently necessary for future usage, for example for heating, transport, or other purposes. This is an area that has a lot of potentials, even if it may be an inefficient process. In this article, we described various approaches to energy storage in general and energy storage based on hydrogen in particular. Hydrogen-based storage is a promising energy storage technology which might be examined further in future research.

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