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Production of Hydrogene and Environmental Impact of Storage the Energy Produced by Renewable Energies Via Hydrogen in Proton Exchange Membrane Fuel Cell

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ABSTRACT

Following the developments realized in recent years after the industrial revolution, a collective awareness of the need to protect and sustain the environment has emerged, mainly due to climate change, increased greenhouse gas emissions and depletion of natural fossil resources (oil, natural gas, coal, etc.). All these difficulties lead the humanity to think of improving the existing solutions, as well as to look for cleaner alternatives such as renewables energies for the satisfaction of the growing demand of energy needs and at the same time respond the climatic requirements at once. The difficulty of this later that must be overcome is the ability to store efficiently the energy produced in the form of electricity in clean and renewable energy production sites such as (the wind, photovoltaic,…), so that it can be used as needed. However, the electricity cannot be stored directly; therefore, it is necessary to convert electricity into storable and removable energy. The principle is to store energy from renewable sources via an electrolyzer, which converts electricity into hydrogen and oxygen during low consumption hours. This energy is returned to the grid via a fuel cell (which converts hydrogen and oxygen back into electricity) during periods of high consumption, especially when intermittent renewable energy sites do not produce anymore. In this perspective, the hydrogen (energy vector) remains one of the best promising solutions and one of the most attractive tracks, thanks to its energy and environmental qualities.

Keywords: Hydrogen, Renewable Energy, Fuel Cell.

I. INTRODUCTION

In order to ensure sustainable development, it is essential to progress towards energy chains that do not increase the amount of greenhouse gasses (GHG) and promote truly renewables sources of energy on the time scale of their consumption by the man. Renewable energies are primary, domestic and clean or inexhaustible resources because they are directly generated from natural phenomena. Therefore, the carbon footprint of these energies is very low [1]. The technologies of these sources of energy are now reaching a certain technical and economic maturity that makes them a success. It mainly produces electricity. However, the sources of the major renewables energies such as hydraulic, wind and solar are intermittent or even random. However, unlike the fossil or fissile energies whom stock is exploited according to needs, In the case of renewable energies that are unstable and unpredictable the aim here is to produce as much as possible of availability of energies, this is because their performance depends on climatic conditions. Only the hydraulic energy is storable in its initial form in dams. However, the other energies, require be immediately consuming or converting into a storable form. To overcome this problem, it would be necessary to be able to store the energy produced in excess and redistribute it when the energy demand is greater. The possibility of massively storing the electricity produced by renewable energies to redistribute it later becomes a primary obligation for the development of this energy sector.

In this perspective, the hydrogen appears as a better solution to store electricity produced by the renewables energies, it also presents as the fuel of the future because of its excellent energy density as well as a very promising candidate for fulfill this function and could become a highly developed energy vector in the future. Many experts see hydrogen as one of the most important energy media of the next century [2]. Providing a closed-loop energy cycle, hydrogen as a renewable energy source, provides the potential for a sustainable development particularly in the transportation sector. Hydrogen-driven vehicles offer the possibility of reducing both, local as well as global, emissions of greenhouse gases. Thus consolidating their potential as part of future transport systems, which inevitably have to be based on renewable energy sources [3]. Unprecedented, who is the idea is to transform energy into hydrogen in order to store it electricity that arrives at the system that feeds a generator of hydrogen which will be able to produce it.

II. Method of production of Hydrogen:

On Earth, hydrogen is associated in nature with many other elements: mainly carbon to form methane (CH_4) and oxygen to form water (H_2O). To obtain pure hydrogen (exactly dihydrogen) for industrial purposes, therefore it must be separated from the chemical elements to which it is bound.

Today, 95% of hydrogen is produced from fossil fuels (natural gas, oil) and wood. Currently, there are various production processes that are advocated, some mastered, remain costly and harmful, others more profitable and cleaner but they still under experimentation.

The most common process for the manufacture of hydrogen is the reforming of gas, the gasification process of charcoal. These processes pollute environment and do not respond to the climatic requirements. But in parallel, the manufacture of hydrogen by electrolysis of water, photo-electrolysis, steam gasification, biomass, microalgae, thermochemical decomposition of water, ..., are more suited to the environment.

In this section, we will detail the different processes of hydrogen manufactured from fossil fuels (natural gas, oil), wood and the most used renewable energies.

II.1 Vapor-forming:

Steam reforming consists in converting the hydrocarbons into syngas by reaction with superheated steam in the presence of a nickel catalyst, at a high temperature (840 to 950 °C) and at a moderate pressure (20 to 30 bar) [4]. In the presence of the water vapor and heat, the carbon atoms (C) and the hydrogen atoms of the methane (CH_4) dissociate. After two successive reactions, they are reformed separately to obtain, on the one hand, dihydrogen (H_2) and, on the other hand, carbon dioxide (CO_2). This process is generally carried out for natural gas. It can also be for methane or naphtha. Depending on the nature of the hydrocarbons used, and the desired hydrogen purity, different methods exist. Hydrocarbons generally contain sulfur, which reacts as a poison for the catalyst used in steam reforming. Therefore, it is necessary to carry out desulfurization (weight content < 0.5 ppm) in order to not to poison the catalyst [5].

The desulfurization operation consists in reacting the feedstock with hydrogen to obtain hydrocarbons and hydrogen sulfide.
The general steam reforming reaction after desulfurization is:

$$C_xH_yO_z + (x-y)H_2O \underset{\leftarrow}{\longrightarrow} \left(x + \frac{y}{2} - z\right)H_2 + xCO \qquad \text{(Eq. 1)}$$

This reaction is accompanied by a number of secondary reactions leading to the formation of methane CH_4, carbon dioxide CO_2 and carbon C. The amount of hydrogen produced depends on the hydrocarbon used.
In general, the steam reforming reaction is followed by a water-gas-shift reaction. This reaction is carried out in two phases, a first catalytic conversion reaction at high temperature (HT), gas cooling and a catalytic conversion reaction at low temperature (BT), which consists of converting the carbon monoxide CO into carbon dioxide CO_2 according to the following equilibrium:

$$CO + H_2O \underset{\leftarrow}{\longrightarrow} H_2 + CO_2 \qquad \text{(Eq. 2)}$$

With $\frac{H_2O}{CO}$ ratio superior to 3, this reaction is complete for a temperature T > 250 °C.

II.2 Partial oxidation (pox) :

Partial oxidation consists, like steam reforming, of converting hydrocarbons into syngas in the presence of oxygen. Partial oxidation may be carried out on more or less heavy products of natural gas, heavy residues, coal or biomass. This reaction takes place at high temperature (900 to 1500 °C) and high pressure (20 to 90 bar) and, contrary to steam, it does not require the presence of a catalyst with an exothermic reaction [5, 6].

The two most known technologies are the Shell and Texaco processes. The two processes differ in the heat treatment mode [5]. Whose general partial oxidation reaction is as follows:

$$C_xH_y + \frac{x}{2}O_2 \xrightarrow[\leftarrow]{} xCO + \frac{y}{2}H_2 \qquad \text{(Eq. 3)}$$

The equation presents the overall result of several reactions, which lead mainly to the formation of CO and H_2 but also to H_2O, C, and CH_4 and hydrocarbons with shorter chains than the starting ones [5]. The problem with this method is the low Production efficiency of hydrogen [6].

II.3 Water electrolysis principle:

The general principle of water electrolysis is the separation of H_2O to dihydrogen and dioxygen in an oxidation-reduction reaction, this method is generally used only if a high purity of hydrogen is required, because it is more expensive the process industrially available at present. It consists in carrying out this electrolysis using electricity.

Electrolysis is a process of chemical decomposition under the action of an electric current.

An electrolysis cell is made up of two electrodes (anode and cathode, electronic conductors) connected to a current generator continued and separated by an electrolyte (ionic conductive medium between the two electrodes) [7]. The electrolyte may be either an acidic or basic aqueous solution or a Proton Exchange Polymer Membrane identical to that used in PEM fuel cells or an ion conductive ceramic membrane [5].

In alkaline media, at the cathode occurs the reduction of water according to equation:

$$2H_2O + 2e^- \xrightarrow[\leftarrow]{} H_2 + 2OH^- \qquad \text{(Eq. 4)}$$

and at the anode, the oxidation of the hydroxide ions according to equation:

$$2OH^- \xrightarrow[\leftarrow]{} \frac{1}{2}O_2 + H_2O + 2e^- \qquad \text{(Eq. 5)}$$

The overall reaction is:

$$2H_2O \xrightarrow[\leftarrow]{} H_2 + \frac{1}{2}O_2 \qquad \text{(Eq. 6)}$$

Although this technique makes it possible to obtain hydrogen of high purity, this technique costs 3-4 times more expensive than other hydrogen manufacturing processes given the high price of electricity. This method is far from having the economic competitiveness of production from fossil sources. But, unlike the use of electricity produced by fossil sources, if we couple the water electrolysis with the electrical production of renewable energies, this will be by far the most promising method as well as it will be the best solution for the storage and exploitation of these energies.

A recent study shows that of all systems of hydrogen production by decomposition of water using renewable energies, the combination of the photovoltaic module for the capture of solar energy and electrolytic cells for decomposition of water is by far the most attractive and simple system [8].

II.4 Organic production (from Microalgae):

Organic production takes place under ambient conditions of temperature and pressure and does not require any energy input, it is also safe for the environment, on the contrary, it allows the development of certain natural resources too often neglected. Organic production of hydrogen is defined as the result of the metabolism of a living organism, which releases hydrogen gas as secondary metabolite under given conditions [9].

Photosynthetic organisms, such as some green algae or cyanobacteria, produce hydrogen during photosynthesis. As well as some modified microbes can produce hydrogen under the effect of sunlight (photosynthetic microbes). The bacteria, so-called Hydrogenase can decompose the format into H_2 and CO_2 [10-12].

Hydrogenases (the enzyme responsible for the production of hydrogen) are enzymes that can reversibly catalyze the oxidation of hydrogen to protons. Therefore, this method does not have simultaneous production of carbon dioxide as in the case of heterotrophic organisms.

Hydrogen production stops rapidly due to the concomitant production of oxygen, which has the effect of inhibiting the hydrogenase. Advances in the understanding of the metabolism of these organisms make it possible today to propose technical solutions to overcome these limitations [11]. This method of photobiological production of hydrogen by algae is nevertheless limited due to certain factors, including the sensitivity of hydrogenase to oxygen, competition between CO_2 fixation and hydrogen production, the saturation of the production capacity of H_2 at low light intensity. The quantity of hydrogen produced by this method remains low [8, 13].

II.5 Photo-electrolysis

Unlike the electrolysis of water using an external source of electricity, photo-electrolysis uses solar radiation directly as the only source of energy to produce hydrogen, without going through the intermediate stage of electricity production. In the presence of a catalyst, the dissociation of the water takes place spontaneously thanks to the solar energy. It consists in illuminating a semiconductor photo-catalyst (an electronic component that decomposes water under the effect of sunlight) immersed in an aqueous electrolyte or in water, the water molecules are then dissociated into oxygen and hydrogen. The problem with this method is the cost of materials such as the platinum constituting the electrodes.

Indeed, the yield of the reaction is conditioned by the absorption of light, or only part of the spectrum is absorbed by the photo-catalyst. This production process is still in need of development with respect to light absorption efficiency, and development of photovoltaic cells.

II.6 Production from biomass:

The production of hydrogen from the biomass is carried out according to two processes depending on the nature of the hydrogen waste [11]:

Either from easily fermentable waste, to produce by methanisation or anaerobic digestion biogas containing 60% methane convertible to hydrogen by reforming. Either from low-fermentable waste, essentially lignocellulosic, one can produce hydrogen by the thermochemical process. The production of hydrogen from biomass has not been exploited in spite of the fact that it is a promising process to be studied. However, the chemical or biochemical technology is relatively complex and requires considerable investment and costly operation.

III. Coupling of hydrogen and PEMFC:

A fuel cell (PEMFC) consists of two electrodes separated by a solid electrolyte: the negative electrode (anode) is supplied with a fuel (hydrogen, methanol, etc.); and the positive one (cathode) with a comburant (oxygen, air, etc.). The electrolyte is a membrane consisting of a protonconducting organic polymer. The most used membranes consist of a skeleton of polytetrafluorocarbon chains bearing acid groups statistically distributed along the chain [14].

Hydrogen and fuel cell are solutions for optimum energy management based on demand. The modularity and flexibility of energy storage and destocking make it possible to supply electricity with low CO2 emissions, regardless of when it is produced, and thus to manage the troughs and peak consumption or when renewable energy is no longer available. These two energy systems are promising in the field of renewable energies and clean energies. This is why the world tends to develop these two technology parallel. Others report that stationary hydrogen applications will have a better overall energy and environmental balance through its use in Fuel Cells. The Fuel Cell Europe association has demonstrated that hydrogen-fired PACs produced from natural gas, although not providing a sustainable source of energy as such, are an effective way to save the inevitable Fossil energy during a transition to a sustainable energy system.

IV. CONCLUSION

In this study, we have shown and detailed the different methods of hydrogen production. The hydrogen production technologies using renewable energies (solar, wind, geothermal and hydraulic) are under development. We have also shown that hydrogen is a way of storing intermittent renewable electricity using surplus electricity in off-peak hours to produce hydrogen.

The most adaptable and developed technique for the moment is to realize the water electrolyzer using renewable source electricity. Studies on the production of hydrogen favors the electrolysis process coupled with electricity from renewable energies. In the face of fossil processes, only the decomposition of biomass or water is capable of also bringing large quantities of hydrogen by reducing greenhouse gases (GHG) emissions. The low-cost production of hydrogen from a renewable source remains one of the major challenges of this century's energy research, as the sector is not yet economically viable

V. REFERENCES

[1]. Y. Naimi, M. Saghir, A. Cherqaoui, B. Chatre, Energetic recovery of biomass in the region of Rabat, Morocco, International Journal of Hydrogen Energy (2016).

[2]. C. Devillers, K. Pehr, J. S. Duffield, D. Weinmann, H. Vandenborre, A. Gonzales, R. Wurster, M. Kester, F. Heurtaux and P. Ekdunge, “European Integrated Hydrogen Project”, 12th World Hydrogen Energy Conference, Buenos Aires, Argentina, 1998.

[3]. R. Boudries-Khellaf, Etude d’un Système de Production d’Hydrogène Solaire en Algérie, Rev. Energ. Ren. : Zones Arides (2002) 17-29.

[4]. G. Bourbonneux, Production d’hydrogène, Le Raffinage du Pétrole, T3 Procédés de transformation, (1998) 463-515.

[5]. D. TIGREAT, Les techniques de production de l’hydrogène et les risques associés, INERIS study report N° DRA-08-95313-07833B, Verneuil en Halatte Oise, 2008.

[6]. M Fleys, Y Simon, P Marqua ire, F Lapicque. Production of hydrogen by partial catalytic oxidation of methane Study of the reaction mechanism. French Society of Process Engineering. French Congres de Génie des Procedes, Oct 2007, Saint-Etienne, France. ISBN 2-910239-70-5 450; 8 pp, 2007, Recent Progress in Process Engineering.

[7]. A.Damien, Hydrogen by electrolysis of water, Techniques of the Engineer. J6366, (1992).

[8]. R. Rihani, R Alloune, A Bensmaili, F Kaidi, M Belhamel New Methods of Hydrogen Production, Center of Renewable Energies, 62. Bouzarea Observatory Road. Algiers Algeria.

[9]. S. Chader, H. Hacene, M. Belhamel and S. Agathos, Etudes des procédés de production biologiques de l’hydrogène, Revue des Energies Renouvelables Vol. 10 N°4 (2007) 497 – 505.

[10]. F.Hoppe -Seyler, Z.physiol.Chem. 11, 561-568, (1887).

[11]. J. Legrand, Hydrogen Memento, Sheet 3.3.2, AFH2.

[12]. L. H. strickland and M. Stephenson, Biochem. J 25, 205-214, (1931)

[13]. S. Kosourov, A.Tsygankov, M. Seibert, M.L Ghirardi, "Sustained hydrogen photoproduction by Chlamydomonas reinhardtii: Effects of culture parameters », Biotechnology and Bioengineering, 78, (2002), 731-740.

[14]. A. Ayad, Y. Naimi, J. Bouet, J.F. Fauvarque, Journal of Power Sources, 130 (2004) 50–55.