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Study to supply Hydrogen at Gas Stations

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Abstract: This paper presents a study on the adaptation of fuel stations to hydrogen fuel, which has recently been gaining ground in the automotive industry because it is used as fuel in hydrogen cells to power the car engine, causing no exhaust gases greenhouse to the earth's atmosphere. With this in mind, the group exposes as a solution to the problem of supplying large quantities of these cars, a possible adaptation of the fuel stations, starting from an electrolytic process fed by solar panels found in the cover of the fuel station, in order separate the hydrogen of water. Scientific articles were used as an aid to this research.

Keywords: Hydrogen, Electrolysis, Gas station.

I. INTRODUCTION

The justification for the project to be made is that nowadays, practically 100% of fossil fuels used in the road transport sector, with a 22% share for the global emission of greenhouse gases. In Brazil, this number is even higher, as this results in a 32% contribution to carbon emissions [1].

Thinking of reducing the emission of these greenhouse gases created by fossil fuel-powered cars, large auto companies (Honda, Hyundai, and Toyota) try to introduce electric automobiles. Electric cars use the energy that comes from a hydrogen fuel cell, with the aim of increase the autonomy of the electric vehicle. Recently, in 2015, the automotive company Honda launched a car with this hydrogen fuel cell, whose pressure is 70 Mpa, reaching the mark of approximately 750km of autonomy [2].

The mass diffusion of this new automobile technology, the concept adopted will be based on the practicality of producing and supplying in the same place, taking into account the coverage area available in the gas station structures and the obtaining hydrogen system by means of water electrolysis, photovoltaic plates can be installed as a power source, in which hydrogen fuel would be produced cleanly [3].

Bearing in mind that there are many articles and works related to the production of hydrogen by means of water electrolysis and the increase in the efficiency of photovoltaic plates through solar irradiations, we believe that it is possible to implement this production logistics, storage and local distribution of hydrogen for vehicles, from an electrolysis system of water powered by solar panels [4].

II. BIBLIOGRAPHICAL REVIEW

Hydrogen H_2 is a gaseous, tasteless, odorless, colorless, and non-toxic chemical element, constituting, in most cases, almost everything around us [5]. For example, water, fuel, plants, animals, etc. Its density has an approximate value of 0.0899 g/l under normal conditions of pressure and temperature [6]. The hydrogen molecule is never found in the free state in nature, being able to produce it through a process of separation of the other elements with which are combined, using which they consume energy, namely by electrolysis and reforming [7-8].

ISO/TS 19880-1: 2016 recommends the minimum design characteristics for the safety and performance of public and non-public hydrogen gas filling stations for vehicles [9]. According to AP2H2 [10], this standard addresses the specifications necessary for the design and construction of a service station for supplying hydrogen, which is:

➢hydrogen production/delivery system;
➢delivery of hydrogen by pipeline, truck in gaseous and liquid hydrogen, or metal hydride storage trailers;
➢local hydrogen generators using the water electrolysis process or fuel processing technologies;
➢storage of liquid hydrogen;
➢hydrogen purification systems, as applicable;
➢hydrogen gas compression;

➢pumps and vaporizers;
➢pre-cooling devices;
➢hydrogen gas dispensers.

Current technologies allow the storage of hydrogen in large quantities in three ways: if it is in a liquid state, low temperatures are the appropriate method to use, around -253 º C; in a gaseous state, the hydrogen gas compression process is used, with high pressures as a characteristic, about 200 Bar; dissolved in other solid substances, according to AP2H2 (2017) [10].

Decentralized energy systems are essential for economic and social development [11], and microgeneration also contributes significantly to decentralization [12].

III. MATERIALS AND METHODS

The project consists of adapting a conventional fuel station for the generation, storage, and distribution of hydrogen fuel. The most suitable electrolysis process for the system and the solar plates for the power supply of the electrolytic chambers are the initial focus. The goal would be to meet the demand for cars that have a hydrogen fuel cell to power the engine.

Initially, the researchers sought to study the structural composition of a gas station, observing its dimensions and the leading equipment used to compose the station.

There was an observation of the possibility of using solar panels, the sizing, and the electrolysis methods used in the industry. The amount of by-product (H_2) that the electrolytic chamber would produce under normal working conditions (pressure and temperature) were targets for study. The adaptation of the post happened although theoretical calculations.

The proposed gas station adaptation system primarily intended the consumers of vehicles that have a hydrogen fuel cell to refuel their car in a short time in an existing structure. The station equipped with photovoltaic plates all over its roof will be the source of energy for the functioning of the electrolytic chamber, which consequently will produce hydrogen and oxygen through water. The hydrogen storage occurs in a low-temperature tank.

The chosen electrolyzer is the HySAT®-10-10 model, available on the Hydrogenics website. This electrolyzer is of the alkaline type. Therefore, it uses salts for a better conductance in the electrolytes, as mentioned in the bibliographic review of this paper.

To determine the photovoltaic panel to be used for the survey data survey, aspects such as power and efficiency prioritized to increase the H_2 production of the electrolysis system. Soon after, the solar panel chosen was the model CS1H-335MS of the CanadianSolar brand.

Table 1 - Solar panel characteristics.

Solar Panel CS1H-335MS	*Product*
Power (W)	335
Operating voltage (V)	36.2
Operation current (A)	9.27
Efficiency (%)	19.86
Maximum system voltage (V)	1000
Width (m)	1.70
Length (m)	0.99
Thickness (m)	0.35

The area available for placing the solar panels on the fuel station roof occurred according to the research by Marcus Cortinhas (2014) [13], which presents the dimensioning of the coverage of a gas station. The area obtained a total of 392.03 m^2.

For the fuel station's fuel supply estimate, it was necessary to determine the volumetric capacity of the hydrogen fuel cell of the car. In this scenario, the values of the Honda Clarity Fuel Cell model were used, with a volumetric capacity of 141 liters inside its cell [3].

From the chosen electrolyzer, we verify its maximum hydrogen production value every hour, as well as its electrical power and energy demand for this production, which will lead us to the total number of solar panels needed to meet these energy demands.

To determine the maximum power demand for the electrolyzer, we multiply its power value per volume (kW/Nm^3) by its maximum hydrogen production (Nm^3) (Eq. 1).

$$P_{max} = PV \times V_{max} \quad \text{(Eq.1)}$$

➢P_{max} = Maximum power demand [kW];
➢PV = Power per volume [kW/Nm³];
➢V_{max} = Maximum volume of hydrogen produced every hour [Nm³].

The results with the application of the values obtained through the electrolytic chamber chosen for the electrolysis process in the formula is (Eq. 2):

$$P_{max} = \frac{5.4kW}{Nm^3} \times 10Nm^3 = 54kW \quad \text{(Eq.2)}$$

The sizing of the photovoltaic system occurs through the maximum demand for the electrical power of the established electrolytic chamber. For calculation purposes, the power of the chosen solar panel must be considered under nominal conditions of solar irradiance (Eq. 3).

$$N_p = P_{max} \times P_p \quad \text{(Eq.3)}$$

➢N_p = Number of solar modules;
➢P_{max} = Maximum power demand [kW];
➢P_p = Solar panel power [kW].

The application of the values acquired through the catalog of the photovoltaic plate chosen in the formula results in the number of modules (Eq. 4).

$$N_p = 54kW \times 0.335kW \cong 162 \quad \text{(Eq. 4)}$$

The number of solar modules rounded up to 162 and with the number of photovoltaic modules that would be needed to supply energy to the electrolysis system, the area that these modules would occupy in the coverage of the fuel station can be calculated (Eq. 5).

$$A_t = N_p \times A_p \quad \text{(Eq. 5)}$$

➢A_t = Total solar abstraction area [m²];
➢N_p = Number of solar panels;
➢A_p = Individual area of each panel [m²].

Each solar module has an area of 1.7 m², so, multiplying this value by the number of solar plates needed to serve as a source for the electrolytic system, we obtain the amount (Eq. 6).

$$A_t = 162 \times 1.7m^2 = 275.4m^2 \quad \text{(Eq. 6)}$$

This number of modules becomes viable, since the total area of the coverage of the station that we are using as a base is 392.03 m^2. The Hours of full Sun Radiation (HSR) is the term used to determine how many hours the solar module receives the nominal incidence of solar irradiance determined by the manufacturer of the photovoltaic plate itself, which in our case is 1kW/m². For this value, it was taken as a basis the dates of average daily solar irradiation monthly (kWh/m².day) in the city of Campo Bom in RS, these values can be found through the CRESESB website [14]. With this, we divide the quantity of energy per area (kWh/m².day) in the city by the amount of power per area standardized by the manufacturer, and we obtain the value of the average daily HSR per month (Eq. 7).

$$HSR = ldmm \times \ln \quad \text{(Eq. 7)}$$

➢HSR = Hours of full Sun Radiation [h];
➢Idmm = Average daily irradiation monthly [kWh/m².day];

➢In = Nominal irradiance of the solar plate [kW/m²].

Using Excel tool, it was possible to produce Table 2, in which each cell corresponding to the HSP column divides the Idmm value for each month of the year by the nominal irradiance of the plate adopted in this case (CRESESB website) [14].

Table 2 - Hours of full Sun Radiation (HSR).

Months (2019)	***Solar irradiation daily average monthly (kWh/m².day)***	***HSR(h)***
Jan	6.24	6.24
Feb	5.71	5.71
Mar	4.75	4.75
Ap	3.78	3.78
May	2.82	2.82
Jun	2.33	2.33
July	2.52	2.52
Aug	3.19	3.19
Sep	3.56	3.56
Oct	4.62	4.62
Nov	6.07	6.07
Dec	6.53	6.53

To calculate the volume of H_2 produced daily each month, the value of HSP multiplicated by the maximum volume of hydrogen produced each hour with Eq. 8:

$$V_d = HSR \times V_{max} \qquad \text{(Eq. 8)}$$

➢V_d = Volume of hydrogen produced per day [Nm²];
➢V_{max} = Maximum volume of hydrogen produced every hour [Nm³];
➢HSR = Peak sun hours [h].

Using the Excel software again, it was possible to view, as shown in Table 3, the values obtained. In each cell corresponding to column Vd, the HSP value is multiplied by the agreed Vmax value, in this case, 10 Nm^3 (Normal Cubic Metric).

Table 3 - Quantity of Hydrogen produced daily each month (V_d).

Months (2019)	***Solar irradiation daily average monthly (kWh/m².day)***	***HSR(h)***	***V_d (Nm^3)***
Jan	6.24	6.24	62.4
Feb	5.71	5.71	57.1
Mar	4.75	4.75	47.5
Ap	3.78	3.78	378
May	2.82	2.82	28.2
Jun	2.33	2.33	23.3
July	2.52	2.52	25.2
Aug	3.19	3.19	31.9
Sep	3.56	3.56	35.6
Oct	4.62	4.62	46.2
Nov	6.07	6.07	60.7
Dec	6.53	6.53	65.3

IV. RESULTS AND DISCUSSION

From the daily production values of each month, we calculate the number of vehicles that could be refueled per day in the different months, taking into account the volume of the hydrogen fuel cell of the Clarity Fuel Cell vehicle belonging to Honda. The size of your tank, in liters, will pass the values of V_d obtained in Nm^3 for liters, where we have that 1 Nm^3 = 1000 L.

Multiplying the values of V_d present in Table 4 by 1000, we obtain the volume of V_d in liters (L), as shown in Table 4.

Table 4 - Quantity of Hydrogen produced daily each month (V_d).

Months (2019)	***Vd (Nm^3)***	***V_d (L)***
Jan	62.4	62.400
Feb	57.1	57.100
Mar	47.5	47.500
Ap	378	37.800
May	28.2	28.200
Jun	23.3	23.300
July	25.2	25.200
Aug	31.9	31.900
Sep	35.6	35.600
Oct	46.2	46.200
Nov	60.7	60.700
Dec	65.3	65.300

To obtain the number of cars that can be supplied per day in the different months of the year, we divide the total daily volume by the volume of the tank of each vehicle. Taking into account that the Clarity Fuel Cell has a 141-liter tank, we arrive at Table 5 with Eq. 9.

$$N_v = V_d \times V_t \qquad \text{(Eq. 9)}$$

➢N_v = Number of cars serviced per day;
➢V_d = Total daily volume [L];
➢V_t = Tank volume of the conventional vehicle [L].

Table 5 - Daily car supply capacity in the respective months.

Months	***Vd (Nm^3)***	***Cars number***
Jan	62.4	443
Feb	57.1	405
Mar	47.5	337
Ap	378	268
May	28.2	200
Jun	23.3	165
July	25.2	179
Aug	31.9	226
Sep	35.6	252
Oct	46.2	328
Nov	60.7	430
Dec	65.3	463

From the data obtained, the study reveals that December has a higher number of vehicles to be supplied with the amount of hydrogen production by the electrolysis process, reaching the value of 463 cars to be filled per day. The month of June is classified as the worst month to supply automobiles, entering the number of 165 vehicles refueled per day. The fuel production capacity of this system depends on the solar irradiance. The production capacity of H_2 has changed according to the seasons. In summer, the solar incidence in the southern hemisphere is higher, and as winter approaches, its hydrogen production decreases. In our work, we used the formula that estimates HSR in a fixed solar irradiance value, and this HSR value used to determine the working time of the electrolyzer at its maximum energy demand.

V. CONCLUSIONS

We can consider that the research results indicate that the use of hydrogen to supply vehicles is feasible, with the hydrogen obtained with the use of photovoltaic modules. However, the project must still continue to obtain the necessary information to define material and dimensions for the storage tank, considering the large amount of hydrogen produced by electrolysis in the case studied.

Building a largely hydrogen-based economy is a long-term process that still depends on extensive research and technological development work in various areas of science and engineering. A breathtaking job requiring small and constant steps with contributions at various levels and at various scales, including small contributions like the one intended with this work.

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REFERENCES

[1] T. Bacquart, K. Arrhenius, S. Persijn, A. Rojo, F. Haloua, et al., Hydrogen fuel quality from two main production processes: Steam methane reforming and proton exchange membrane water electrolysis, Journal of Power Sources, vol. 44431, 2019. DOI 10.1016/j.jpowsour.2019.227170

[2] S. K. Mazloomi, N. Sulaiman, Influencing factors of water electrolysis electrical efficiency. Renewable and Sustainable Energy Reviews, vol. 16, n. 6, p. 4257–4263, 2012. DOI: 10.1016/j.rser.2012.03.052

[3] Honda. Honda mostra o inovador Clarity Fuel Cell no Salão do Automóvel de São Paulo. Available in: < https://www.honda.com.br/noticias/honda-mostra-o-inovadorclarity-fuel-cell-no-salao-do-automovel-de-sao-paulo>

[4] L. Mastropasqua, I. Pecenati, A. Giostri, S. Campanari, Solar hydrogen production: Techno-economic analysis of a parabolic dish-supported high-temperature electrolysis system, Applied Energy, vol. 2611, 2020. DOI: 10.1016/j.apenergy.2019.114392

[5] X. Shi, X. Liao, Y. Li, Quantification of fresh water consumption and scarcity footprints of hydrogen from water electrolysis: A methodology framework, Renewable Energy, vol. 154, 2020. pp 786-796. DOI: 10.1016/j.renene.2020.03.026

[6] J. E. O'Brien, J. L. Hartvigsen, R. D. Boardman, J. J. Hartvigsen, S. Elangovan, A 25 kW high temperature electrolysis facility for flexible hydrogen production and system integration studies, International Journal of Hydrogen Energy, In press, 2020. DOI: 10.1016/j.ijhydene.2020.04.074

[7] A. Nicita, G. Maggio, A. P. F. Andaloro, G. Squadrito, Green hydrogen as feedstock: Financial analysis of a photovoltaic-powered electrolysis plant, International Journal of Hydrogen Energy, vol. 45, n. 2014 2020, pp 11395-11408. DOI: 10.1016/j.ijhydene.2020.02.062

[8] M. F. Andrea, R. H. Sara, D. Z. Luca, S. S. Giovanni, B. Enrico,Techno-economic analysis of in-situ production by electrolysis, biomass gasification and delivery systems for Hydrogen Refuelling Stations: Rome case study, Energy Procedia, vol. 148, 2018. pp 82-89. DOI: 10.1016/j.egypro.2018.08.033

[9] Associação Portuguesa para a Promoção do Hidrogênio. Norma ISO/TS 19880-1:2016. AP2H2, 2017. Available in: <http://www.ap2h2.pt/documentos.php?id=5>

[10] Associação Portuguesa para a Promoção do Hidrogênio. Sobre o hidrogênio. AP2H2, 2017. Available in: http://www.ap2h2.pt/sobre-h2.php

[11] E. Schein, M. C. Santos, J. Souza, G. B. Alves, E. G. Rossini, A. Beluco, Estudo de implantação de energia solar em unidades produtivas de uma empresa de calçados no nordeste brasileiro. Brazilian Journal of Development Vol. 5, n. 12, p. 30327-30340 (2019). DOI:10.34117/bjdv5n12-158

[12] G. Vasco, J. S. Silva, F. A. Canales, A. Beluco, J. D. Souza, E. G. Rossini, A Hydro PV Hybrid System for the Laranjeiras Dam (in Southern Brazil) Operating with Storage Capacity in the Water Reservoir Smart Grid and Renewable Energy, 10, (2019) pp. 83-97. DOI: 10.4236/sgre.2019.104006

[13] C. de C. Marcus, Dimensionamento da cobertura de um posto de combustível. Undergraduate thesis. Universidade Federal de Santa Catarina 2014. Available in: https://repositorio.ufsc.br/handle/123456789/122241
[14] CRESESB - Centro de Referência para as Energias Solar e Eólica Sérgio de Salvo Brito. http://www.cresesb.cepel.br/

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