Analysis of the feasibility of methane production through application of the Sabatier process and based on renewable energy-sourced hydrogen production.

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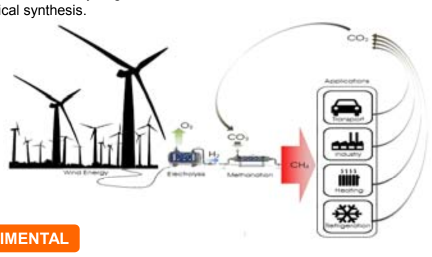
1. INTRODUCTION

The main aim of this work is the analysis of the technical and economic feasibility of the production of synthetic gas via application of the Sabatier reaction.
Using wind energy resources, hydrogen is obtained through an electrolysis process. This hydrogen is combined with carbon dioxide which can be obtained from various sources including, for example, emissions generated by industrial combustion processes, treatments for the degradation of organic matter, wastewater sludge treatment, etc.
The reaction between hydrogen and carbon dioxide is converted into methane in a thermochemical synthesis.

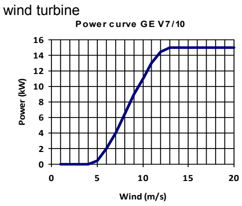


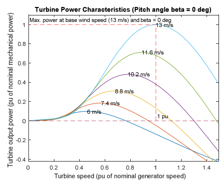
2. EXPERIMENTAL

The design is undertaken in this study of a methane production system, the operation of which is simulated using Matlab-Simulink software. This simulation enables an analysis of the behaviour of a wind generation system connected to an electrolyser and the subsequent production of methane via the synthesis of hydrogen and carbon dioxide through application of the Sabatier process.

2.1. Wind turbine model

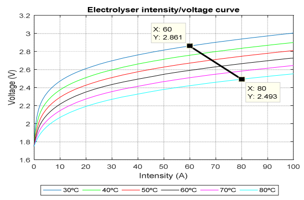
The characteristic curves used in this study are shown in the next figures for Vergnet GEV 10/15 wind turbine





2.2. Electrolyser mathematical model

The behaviour of the electrolyser is based on the curve which represents the terminal voltage of an electrolytic cell against the intensity, as seen in the next figure.



As the operating temperature is increased for the same cell voltaje, the intensity crossing it rises. From an energy-based point of view, as the temperature rises hydrogen production becomes more efficient as less electrical power is required

2.3. Reactor mathematical model

The Sabatier reaction is a process involving the reaction:

$$H_2 + CO_2 \longrightarrow CH_4 + 2\,H_2O \qquad \Delta H = -167 KJ/mol$$

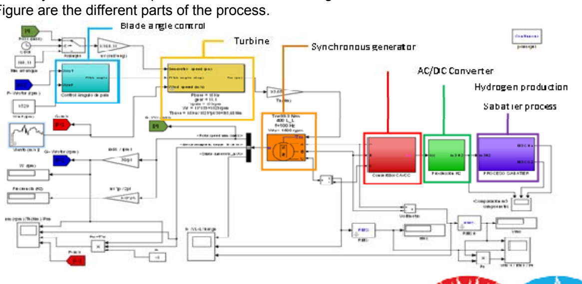
The initial molar ratio is 4:1 and the temperature ranges from 200 to 600 ºC. It is a heterogenous reaction taking place in the presence of metal catalysts.

The behaviour of the reactor is based on the kinetics of the reaction which expresses the progress of the Sabatier reaction, in the form:

$$q = k^n_f\,[CO_2]^n\,[H_2]^{4n} - k^n_r\,[CH_4]^n\,[H_2O]^{2n} \ (mol/cm^3s)$$

2.4. Simulation

An analysis of the whole process was simulated using the Matlab-Simulink software. Shown in Figure are the different parts of the process.

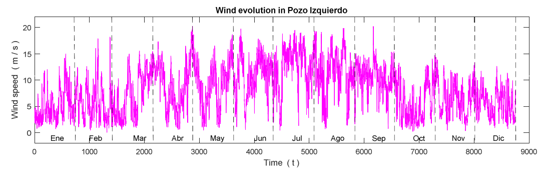


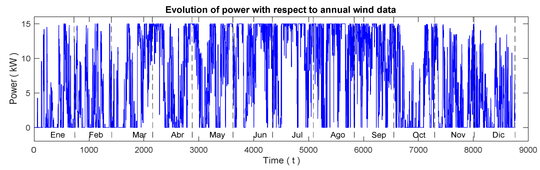
3. RESULTS AND DISCUSSION

After an analysis of the various scenarios, the technical feasibility of the system was determined.
To assess the feasibility of the study, a comparison was made between the simulated data and the actual wind data obtained over a year at the facilities of the Technological Institute of the Canary Islands (Spanish initials: ITC), located in Pozo Izquierdo on the island of Gran Canaria, Spain.
The purpose of the comparison was to:

3.1. Represent turbine efficiency and power

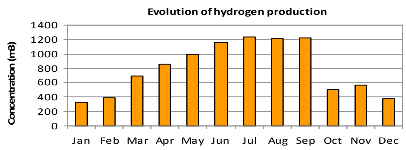
The figure shows the evolution of wind speed over the course of 2010. Using these data, the power values for the characteristics of our wind turbine were obtained, which were then used to obtain hydrogen.





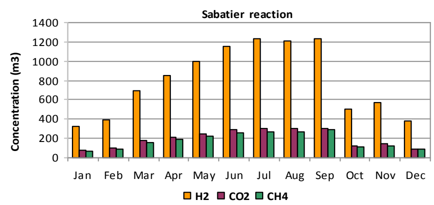
3.2. Represent hydrogen concentrations that would be obtained

The next figure shows the evolution of hydrogen production



3.3. Evaluate the concentration of carbon dioxide that will be combined with hydrogen to form methane.

The figure represents the monthly required concentrations of reagents, both hydrogen and carbon dioxide, to produce the methane.



With respect to its economic feasibility, it is noted that current production costs for natural gas are more economical than those for the proposed production of synthetic gas, with a natural gas sale cost of 0.8 €/Kg and a synthetic gas production investment cost amounting to 26.46 €/Kg.

4. CONCLUSIONS

- This analysis is based on an innovative technological development as a future investment for modification of current energy systems based on the use of non-renewable fossil fuels. Such a project will become economically viable as fossil fuel production approaches a minimum and extraction costs a maximum.
- The system considered in this study can be considered an alternative as a stand-alone system, given the many population centres throughout the world which have no grid connection to supply their energy requirements.
- Synthetic methane can basically be produced at any location with water, air and renewable energy source availability.
- Another innovative aspect is the reuse of carbon dioxide, with the environmental benefit of contributing to the reduction of greenhouse gas emissions given that a closed cycle is created and carbon dioxide emissions are controlled.

5. ACKNOWLEDGEMENTS

In appreciation for the Fundación Universitaria de las Palmas, for you research scholarship of the program Innova Canarias 2017.
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