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Article

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Hydrogen Production from H2SO4 Cycle, and Solar Parabolic trough Collector System in City of Tamanrasset

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ABSTRACT

Covering the energy demands for the future generation under Algerian climate became a strong debate in the last 3 years, especially after oil crisis. One of the solutions is exploiting solar energy due to the solar irradiation availability in the country. Application of this renewable energy resource is used to produce electricity through photovoltaic panels in different zones of Algeria. However, exploiting thermal solar energy is considered one of the most important existing technologies to produce green energy sources such as hydrogen. This paper is focusing in coupling between solar parabolic trough collector systems, with H2SO4 thermo-chemical cycle to produce Hydrogen. Both seasonally and annually, of solar irradiation have been taken from different positions in city of Tamanrasset which is located in south of Algeria. The obtained results explain the possibility to produce hydrogen from H2SO4 thermo-chemical cycle through thermal solar energy, with considerable efficiency instead using nuclear energy.

Keywords: Solar Energy, Hydrogen Production, H2SO4 Cycle, Tamanrasset
JEL Classifications: Q42, Q43

1. INTRODUCTION

Till today, extensive researches have been developed about renewable energy, especially solar energy for hydrogen production under Algerian climate. This paper consists two different parts which are: Understand thermal solar energy system, and hydrogen production from H2SO4 to increase energy efficiency, and develop the economy of the country. Using thermal solar energy has become one of the most important debates to cover energy demands, especially after the oil crisis in the last 3 years. In fact, solar energy is the dominant renewable energy resource in the Algeria due to the availability of solar irradiation in a lot of zones. Integrating this resource, with thermo-chemical cycle is considered a positive solution to produce hydrogen, and replace the fossil fuel in the next decade. Developing clean energy such as hydrogen from renewable energy resources needs a deep knowledge about combination between thermo-chemical cycles, and the choice of the suitable thermal solar energy system. $H_2SO_{4\ cycle}$ has been selected to produce hydrogen from solar energy instead nuclear energy, which affects the environment at high temperature. The available data is based on combination between solar parabolic trough collector systems, with H_2SO_4 cycle for hydrogen production. Both seasonally and annually, of solar irradiation have been measured in different positions in city of Tamanrasset (Mohamed, 2002).

This paper is focusing in transforming the measured solar irradiation to H_2SO_4 cycle through a solar parabolic collector system for hydrogen production in city of Tamanrasset. In terms of Hydrogen production; an analytical process has been proposed to explain the goal of combination between green energy resources for the future generations. The available data in Algeria about thermal solar energy system is existing in the south of the country where the city of Tamanrasset is located. The contribution in this paper is production of hydrogen from H2SO4, and solar system instead of nuclear energy technology. Extensive research papers about hydrogen production from H2SO4 cycle, and thermal solar energy have been developed. Investigation of hydrogen production from H2SO4 by a water-splitting reaction, with an experimental results on thermal dissociation of sulphuric acid for hydrogen production has been discussed through studying Catalytic thermal decomposition of sulphuric acid in sulphur–iodine cycle by

(Barbarossa et al., 2006). Another research has been proposed about a new design, and thermodynamic and engineering analyses of the H_2SO_4 decomposition section By (Öztürka and Hammache, 1995), to improve the process for H_2SO_4 decomposition step of the sulfur-iodine (SI) cycle. The obtained results showed that energetic and exergetic efficiencies are 76.0 and 75.6%, respectively. However, Yanwei et al., have studied detailed kinetic modeling of homogeneous H_2SO_4decomposition in the sulfur–iodine cycle for hydrogen production. The results of sensitivity analysis described that elementary reactions of the proposal cycles had important functions in SO_3 decomposition (Yanwei et al., 2014). Reducing the amount of iodine and water introduced in Bunsen reaction of through optimization of the SI thermo-chemical cycle has been developed by (Sonia et al., 2006) by realizing an experience to study of Bunsen reaction in the framework of massive hydrogen production by the SI thermo-chemical cycle, First results showed that increasing the amounts of I2 lead to better HI and H2SO4 separation in each of the two liquid phases. In higher cycle efficiency the conventional sulfur cycle for hydrogen production process has been developed by (Lu, 1983), to study the sulfur dioxide depolarized electrolysis for hydrogen production. As a result, using a solid oxide electrolyte, with sulfure based cycle is accepted.

Study of the thermo-chemical water-splitting iodine–sulfur process for effective hydrogen production has been developed by (Seiji et al., 2002), to understand water-splitting iodine-sulfur (IS) process for hydrogen production with the use of nuclear technology at temperatures close to 1000 C (Struck et al., 1982), have been constructed a model by studying a three-compartment electrolytic cell for anodic oxidation of sulfur dioxide and cathodic production of hydrogen, to minimize ohmic resistance avoiding the cathodic reduction of sulfur dioxide. Regarding combination solar thermal energy, with H2SO4 cycle (Bilgen, 1988), Has been studied solar hydrogen production by hybrid thermo-chemical processes, to improve the solar chemical process which is based on the sulfur family cycles. However, (George et al., 2011), have been developed a model about Hydrogen production via sulfur-based thermo-chemical cycles which consists three part. The obtained results, explain that coupling fresh and spent catalysts, with characterization results is used to identify the possibility of the proposal model mechanisms with more efficient catalytic systems. Finally, (Robert et al., September 28–October 1, 2008) have been developed an experience on the SI Thermo-chemical Cycle for Hydrogen Production, and it was the first time the S-I cycle has been realized using engineering materials to produce hydrogen.

2. HYDROGEN PRODUCTIVITY FROM H2SO4 CYCLE THROUGH THERMAL SOLAR ENERGY

Studying chemical reactions of H2SO4 cycle at high temperature (20°C–900°C); generated by solar parabolic trough collector system is considered an efficient way to replace nuclear energy by solar energy. The productivity of hydrogen from H2SO4 cycle is 295,500 MJ/KgH2 (Xingl and Ryutaro, 2011). Table 1 shows the hydrogen productivity from H2SO4.

3. HYDROGEN PRODUCTION FROM SOLAR ENERGY AND H2SO4 CYCLE AS A FUTURE SOLUTION

Coupling thermal solar system, with hydrogen production from H2SO4 cycle at temperature between 20°C and 900°C, through solar parabolic trough collector system has proofed that solar parabolic trough collector system, is the suitable pathway for the proposal process. Table 2 shows the suitable thermal solar energy system for hydrogen production from H2SO4 cycle.

4. DESCRIPTION OF THE PROPOSAL MODEL

Design of the proposal model is based on combination between thermal solar energy system, and H2SO4 thermo-chemical cycle. The process of hydrogen production is given by Table 3 which has been developed through many previous papers.

Description of the proposal studied model is divided into three major steps:

- In the solar field: The thermal fluid which is circulating in the solar parabolic trough collector system is helium for obtaining

Table 1: Hydrogen productivity from solar thermal energy and H2SO4 cycle

Hydrogen cycle production	Productivity of hydrogen MJ/kgH2
H2SO4 cycle (Xingl and Ryutaro, 2011)	295,500 MJ/KgH2 (Xingl and Ryutaro, 2011)

Table 2: The suitable thermal solar energy system to H2SO4 cycle

Thermal solar technology for hydrogen production	Efficiency %	Temperature °C
Parabolic trough collector (Evangelos and Antonopoulos, 2017)	42.21%	>826.85

Table 3: Process of producing the hydrogen from H2SO4 cycle

STEP	Chemical reaction	Temperature	Thermal power
Exothermic	I2+SO2+2H2O→2HI+H2SO4	20−120°C	ΔH=−75(±15) kJ/mol)
Endothermic	2H2SO4→2H2O+2SO2+O2	600−900°C	ΔH=+186(±3) kJ/mol)
Endothermic	2HI→H2+I2	300−450°C	ΔH=+12 kJ/mol

the necessary temperature (20°C–900°C) to generate hydrogen from H2SO4 cycle.

- Helium is used in solar parabolic trough collector system because it's ability to increase the temperature up to 1000°C.
- The proposed model mentions that there is one pathway for hydrogen production through H2SO4 cycle (Figure 1).

The calculation of the studied case is based on hydrogen productivity from H2SO4 cycle (Table 4).

- Measuring the solar irradiation in the city of Tamanrasset.
- Motivated the solar irradiation by the efficiency of the selected solar system.
- Compare the energy obtained with the productivity of hydrogen (the necessary power to produce one Kg of H2) from each cycle.

5. RESULTS AND DISCUSSION

The obtained results show that seasonally and annually, thermal solar capacity in the country and the hydrogen production potential produced through H2SO4 cycle, from solar parabolic concentrators.

Figure 2 shows the difference between the solar irradiation obtained from the solar parabolic trough collector system, and thermal solar capacity measured in city of Tamanrasset. The global solar radiation is the highest value which is considered

Figure 1: Thermal solar energy for hydrogen production

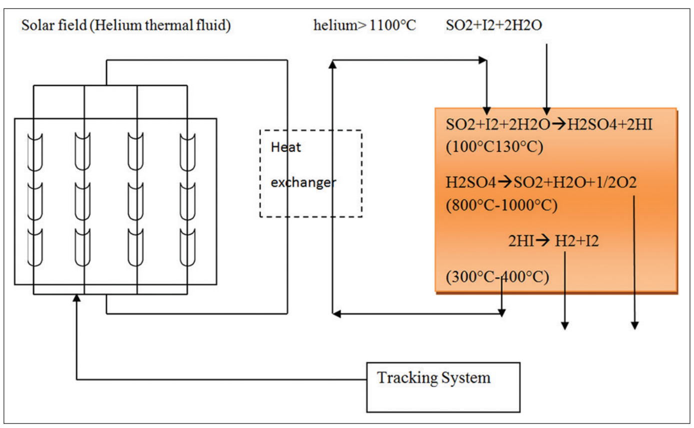
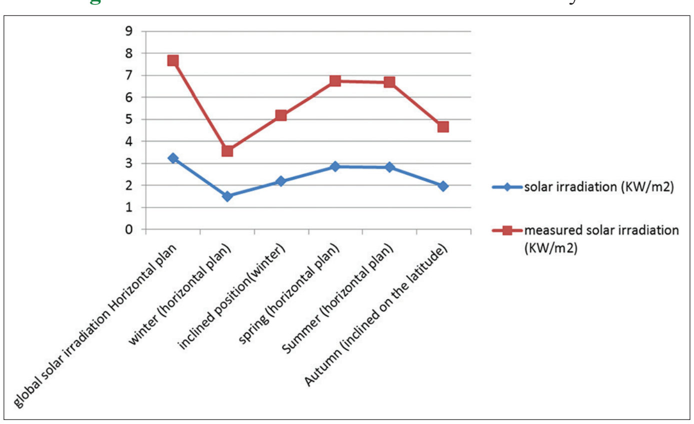


Figure 2: Solar irradiation obtained from the solar system



around 43%, with helium as thermal fluid from the proposal solar system. Comparing to solar photovoltaic system, with energy efficiency between 15% and 23%, the solar parabolic trough collector system is much better for hydrogen production through H2SO4 cycle.

Figure 3 explains the impact of solar parabolic trough collector system on amount of hydrogen produced, through H2SO4 cycle. The highest value is around 0.27 $KgH_2/m^2/day$, and the lowest value is around 0.13 $KgH_2/m^2/day$. The efficiency of hydrogen production from H2SO4 is linked to the solar irradiation in the studied zone, and the positions of the thermal solar system.

Figure 4 describes the solar irradiation absorbed by thermal solar system for hydrogen production through H2SO4 cycle. From the obtained results it is clear that solar irradiation has a strong impact on the amount of hydrogen produced. As a result, the selected thermal solar system has increased the energy efficiency to around 43% comparing to photovoltaic system which is 23%, so exploiting solar system for hydrogen production is considered the best pathway for hydrogen production though H2SO4 cycle.

Figure 3: Hydrogen produced from H2SO4 cycle through solar system

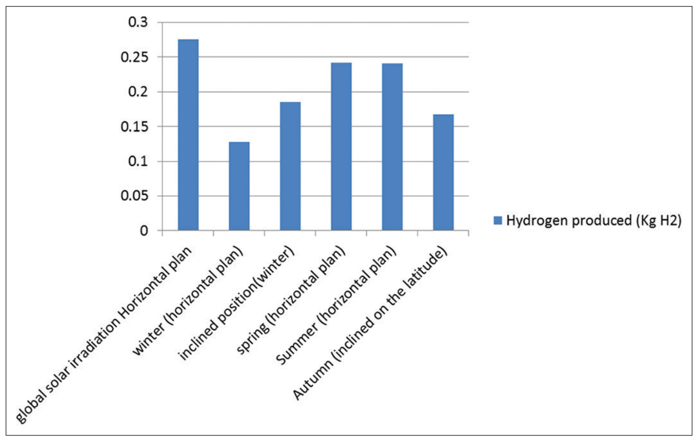


Figure 4: Solar irradiation absorbed by thermal solar system for hydrogen production

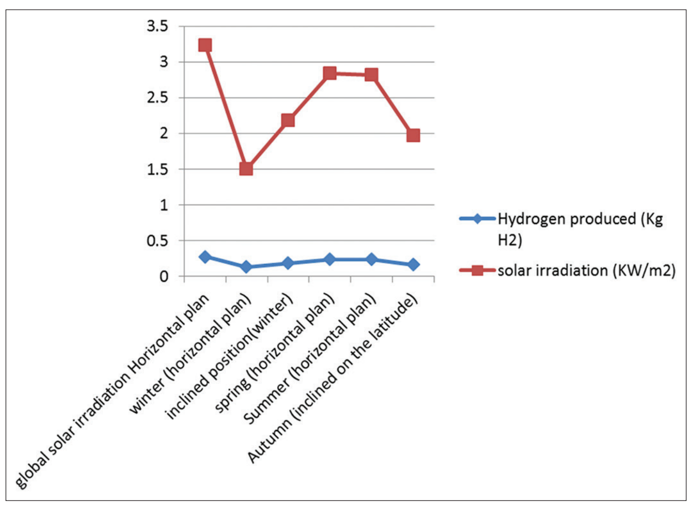


Table 4: Mathematical calculation of hydrogen production from H2SO4 cycle in city of Tamanrasset

Cycle	Solar irradiation (W/m^2)	Efficiency of solar system (%)	Hydrogenproductivity (MJ/KgH2)
H2SO4 cycle	Measured	42.21% (>826.85°C) (Evangelos and Antonopoulos, 2017)	295,5 MJ/Kg2 (Xingl and Ryutaro, 2011)

6. CONCLUSION

Combination thermal solar energy systems, with thermo-chemical cycle have produced a new green source of energy which is hydrogen. The amount of hydrogen produced in city of Tamanrasset is considered an important value to cover the energy demands for the next generations. Solar parabolic trough collector system is considered the right solution to replace nuclear energy for hydrogen production from H2SO4 cycle. As a conclusion, it is possible to produce hydrogen from H2SO4 cycle, through solar parabolic trough collector system under Algerian climate.

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