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SIMULATION OF HYDROGEN PRODUCTION SYSTEM WITH PARABOLIC HYBRID SOLAR COLLECTOR

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ABSTRACT
In this study the simulation of hydrogen production system was done by using hybrid solar collector with electrolysis of water. The mathematical model was set up according to the systems flowchart. For these numerical studies, Istanbul, Konya, and Erzurum ,western, middle, and eastern of Turkey were considered. Borland Delphi 7 programming language was used for the numerical studies. The solar time and solar irradiance of these three cities were taken into consideration and the values for these cities were compared to each other. It was considered that Konya was more convenient than Istanbul and Erzurum for hydrogen and oxygen production.

In addition, pressure had a very low effect on hydrogen and oxygen production; and the effect of heat was very high.

Keywords: Hybrid collector, Electrolysis of water, Hydrogen production

1. INTRODUCTION
There were many studies on hydrogen production by means of electrolysis of water from solar energy. In order to increase hydrogen production a lot of methods were used. For example different types of electrolysers at different pressure values were used.

Carpetis [1], used the electrical energy and executed the electrolysis of water with the photovoltaic solar energy conversion. He compared the results of calculation with available experimental data and the performance of the hydrogen production plant. Morner , Beckman and Klein [2], compared the results of Schatz solar-hydrogen project with the simulation of photovoltaic-hydrogen system results.

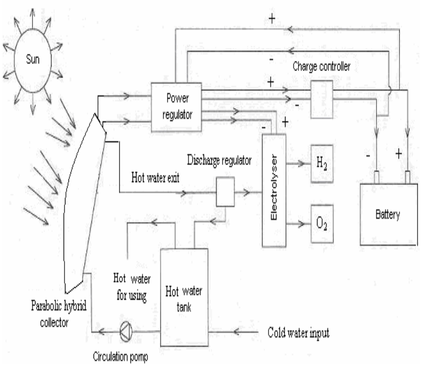
Gretz [3],studied the potential of solar energy conversion into hydrogen and other fuels , and examined the conditions related to the thermodynamics and energy for water decomposition. He discussed different water decomposition techniques. Tani , Sekiguchi , Sakai and Ohta [4],studied about optimization of solar hydrogen systems taking into consideration the hydrogen production cost. They produced hydrogen with a hydrogen generator. The required voltage was supplied by a photovoltaic module. They analyzed the system's current / voltage characteristics. Lich , Wang , Mukerji , Soga , Umeno and Tributch [5], studied the attainable efficiency of solar energy conversion in water decomposition and observed the conversion perform with different semiconductors.

Kharkats and Pleskov [6], studied the solar energy conversion to electrical and heat energy, and they searched about the solar energy storage systems. They studied the solar radiation, the decomposition and the characteristics of battery storage and systems optimization point under different design conditions. Torres , Rodriguez and Sebastian [7], simulated the system which housed the photovoltaic array , electrolyser , fuel cell, hydrogen tank and battery; and they compared the results for different locations in Mexico.

Padin , Veziroğlu , Shahin [8],designed and simulated a new hydrogen production system by electrolysis of water using hybrid solar collector at high temperatures, and saw that the results were doubled productive according to the classical hydrogen production systems.

2. THEORY

By using hybrid solar collectors at high temperatures the water electrolysis was performed; and the system's flow chart prepared. The mathematical model of the system's component (hybrid collector, electrolyser, hydrogen and oxygen storage tank, battery , hot water storage tank) was made. By Borland Delphi 7 programming language, the numerical calculations for Konya , Istanbul and Erzurum were done by taking into consideration the solar time and solar irradiance for twelve months. In Figure 1 the block scheme of the system which was producing hydrogen at the high temperatures by performing water electrolysis with a parabolic hybrid collector was shown. The system consisted of the parabolic hybrid collector, the electrolyser, the battery, the debut regulator, the power regulator, the battery charge controller, the pomp and hot water storage tank. In Figure 2 the flow diagram of the afore mentioned system was prepared according to the system block scheme.



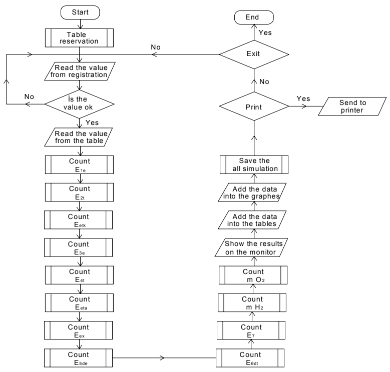


Figure 1. The block scheme of the system

Figure 2. The flow diagram of the system

Energy entering the system in the decomposition process of hydrogen and oxygen from water is equal to the change an enthalpy [8],

$$\Delta H = \Delta G + \Delta Q = 79\,W/mol \tag{1}$$

Where ΔG , stands for Gibbs free energy, and ΔQ is the change in the thermal energy.
The solar energy in the hybrid collector transfers into the electrical and thermal energy. The produced electrical energy is written as follows,

$$E_{1e} = \eta_e A q_t R \tag{2}$$

The thermal energy is produced;

$$E_{2t} = \eta_t A q_t R \tag{3}$$

The total energy is produced in the hybrid collector is,

$$E_{etk} = E_{1e} + E_{2t} \tag{4}$$

Where the values of E1e and E2t are substituted in equation 14, the following formulation are obtained.

$$E_{etk} = \eta_e A q_t R + \eta_t A q_t R$$

$$E_{etk} = A q_t R(\eta_e + \eta_t) \tag{5}$$

The electrical energy entering into the electrolyser follows to ways.the electrical energy goes into the power regulator. Some of that goes into the electrolyser; and the remainder goes into the electrical storage system for use in inadequate energy time of solar. The power regulator ensures the electrical energy for the electrolyser. The electrical energy entering into the electrolyser [9] is

$$E_{3e} = (U + R_t J - 6{,}5.10^{-5} T \ln P)n \tag{6}$$

Where,

U : Potential required for the decomposition unit mass of water

R1 : Total cell resistance , J : Current , n : Cell number
The thermal energy entering into the electrolyser is

$$E_{4t} = T\Delta S / t \qquad (7)$$

Where,
ΔS: The entropy changing for the decomposition per unit mass of water, which is 116 J / K
t : Time
The total energy required for the electrolyser is

$$E_{eta} = E_{4t} + E_{3e} \qquad (8)$$

The total energy produced by the hybrid collector is higher than the total energy consumed by the electrolyser. This discrepancy results in extra energy the forming for determing the exact amount of extra energy produced. Therefore, extra energy is written as follows.

$$E_{ex} = E_{etk} + E_{eta} \qquad (9)$$

The energy produced in the hybrid collector goes into the electrolyser. And the extra is stored in the battery. The energy expression of the charge controller is

$$E_7 = \eta_{gr} (E_{1e} - E_{3e}) \qquad (10)$$

The electrically energy is stored in the battery is

$$E_{5de} = E_7 \eta_{ş} \qquad (11)$$

The energy expression of hot water tank is written as follows

$$E_{6dt} = \eta_{dr} (E_{2t} - E_{4t}) \qquad (12)$$

The hydrogen produced in the electrolyser (8) is,

$$m_{H_2} = (E_{eta} / E_{3e}).(1/9) \qquad (13)$$

and the oxygen is,

$$m_{O_2} = (E_{eta} / E_{3e}).(8/9) \qquad (14)$$

3. SIMULATION

The simulation of the system was done with monthly average irradiance and sun time of Konya , Istanbul , and Erzurum cities at the different temperatures and pressures.
In this simulation, the efficiency of components which were sub element components of the system was accepted constants.
For each city the temperature was kept constant (373 K); and the pressure was increased up to 0,1 Mpa and 0,5 Mpa. An other experiment, the pressure was kept at a constant (0,1 Mpa) , the temperature was increases up to 573 K. In addition , the temperature and the pressure were increased together up to 0,3 Mpa and 473 K. For each case, a simulation of the system was made.
The average solar irradiance, the solar time, the electrical and the heat energies obtained from the solar collector for these three cities were shown in Figures 3,4,5 and 6 respectively.
The Figures 7 and 8 showned the average electrical energy and average thermal energy consumed by the electrolyser at different pressure and temperatures for these three cities. Figures 9 and 10 showned the average hydrogen and oxygen produced at the different pressures and temperatures for Istanbul, Konya and Erzurum.

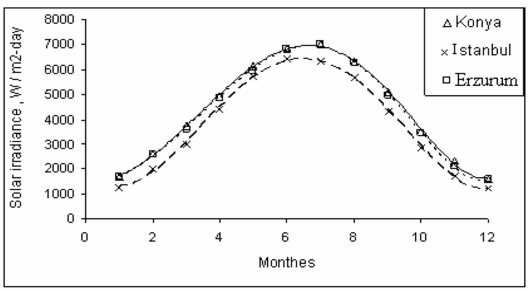


Figure 3. The average irradiance for Konya, Istanbul and Erzurum

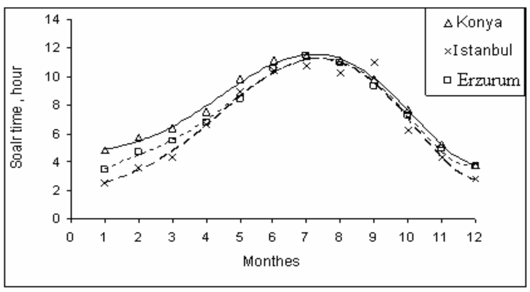


Figure 4. The average solar time for Konya, Istanbul,Erzurum

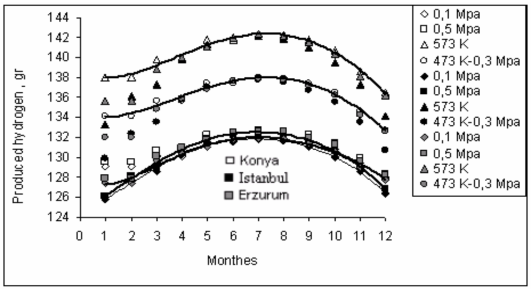


Figure 5. The average amount of hydrogen produced at the different temperatures and pressures for Konya, Istanbul and Erzurum

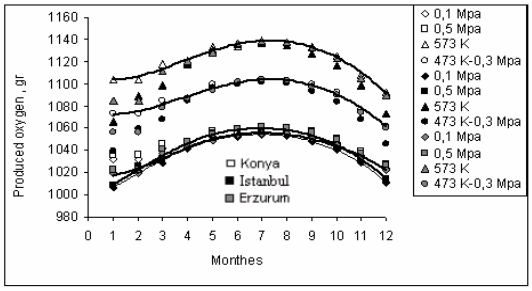


Figure 6.The average oxygen produced at the different temperatures and pressures for Konya, Istanbul and Erzurum

4. CONCLUSION AND EVALUATION

As shown in Figure 3 and 4 if the average solar time and solar irradiance of Konya , Istanbul and Erzurum compared with each other, Konya had the greatest value according to the other two cities.

As shown in Figure 5, the temperature was much important according to the pressure in production of hydrogen. If the pressure and temperature were increased together, an increament to become in production of hydrogen. It was difficult to study at high pressures therefore, the increament of temperature was enough. Where, as shown in Figure 6, the temperature increased, the production of oxygen increased too. From this point of view, it might be said that, the pressures was not important in the production of hydrogen and oxygen neverteles. The temperatures were important factors in hydrogen and oxygen production.

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