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Feasibility Study for a Solar-Energy Stand-Alone System: (S.E.S.A.S.)

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ABSTRACT

The present study is aimed to serve a small community living on Stand-Alone Solar-Energy (S.A.S.E.S.) system. As a basis for the study 1 cubic meter of hydrogen is to be produced by electrolysis in 5 hrs that requires energy input of 5 KW-hr. The proposed system consists of the following main components: photovoltaic module, water electrolyzer and fuel cell. Solar hydrogen production by water electrolysis is described and design parameters are specified. Economic feasibility of the proposed system is evaluated. The projected cost of hydrogen is calculated and found to be 5 cents/ft^3.

Keywords: Hydrogen; Solar Energy; Electrolysis; Fuel Cell

1. Introduction

The sun blasts Earth with enough energy in one hour: 4.3 × 1020 joules to provide all of humanity's energy needs for a year (4.1 × 1020 joules). Solar energy provides electricity via photovoltaic cells. Sunlight reaching the land surface of our planet can produce the equivalence of 1600 times the total energy consumption of the world; the amount of solar energy derived from the sun's radiation on just one square kilometer is about 4000 megawatts, enough to light a small town.

With the eventual exhaustion of conventional fuel resources and the aggravation of environmental damage caused by the use of fuel combustion procedures, the use of hydrogen as an energy source and the development of hydrogen energetics is increasingly the major focus of many research laboratories working in the energy sector.

To have a Solar-Energy Stand-Alone System (S.E.S.A.S.) that provides power around the clock for a community; solar hydrogen is proposed. Solar hydrogen is simply produced by the electrolysis of water using solar energy (photo-electrolytical); one of the promising options of renewable energy sources as illustrated in **Figure 1**.

2. Solar Hydrogen Production by Electrolysis

Hydrogen, the cleanest energy storage in the Universe, is most of the time associated with high costs, although it is extracted from water, which is the cheapest yet the most precious element to life BTU.

Electrolysis is one of the acknowledged means of generating chemical products from their native state [1,2]. In other words, make hydrogen while the sun shines; once produced the stored hydrogen will play a key role in the Solar-Energy Stand-Alone System.

Depending on the fraction of hydrogen produced by electrolysis (values can be up to 85%), the amount of electricity required based on electrolysis efficiency of 100%, would require close to 40 kWh per kilogram of hydrogen—a number derived from the higher heating value of hydrogen, a physical property. However, today's systems have an efficiency of about 60% - 70%, with the Doe's future target at 75%. This can boost the amount of energy required to produce one kilogram of hydrogen from 40 kWh to more than 50 kWh.

The cost of hydrogen production is an important issue. For comparison hydrogen produced by steam reforming costs approximately three times the cost of natural gas per unit of energy produced. This means that if natural gas costs $6/million BTU, then hydrogen will be $18/million BTU. While more expensive than steam reforming of natural gas, electrolysis may play an important role in the transition to a hydrogen economy because small facilities can be built at existing service stations. In addition, electrolysis is well matched to intermittent renewable technologies. Finally, electrolyzers can allow distributed power systems to manage power during peak.

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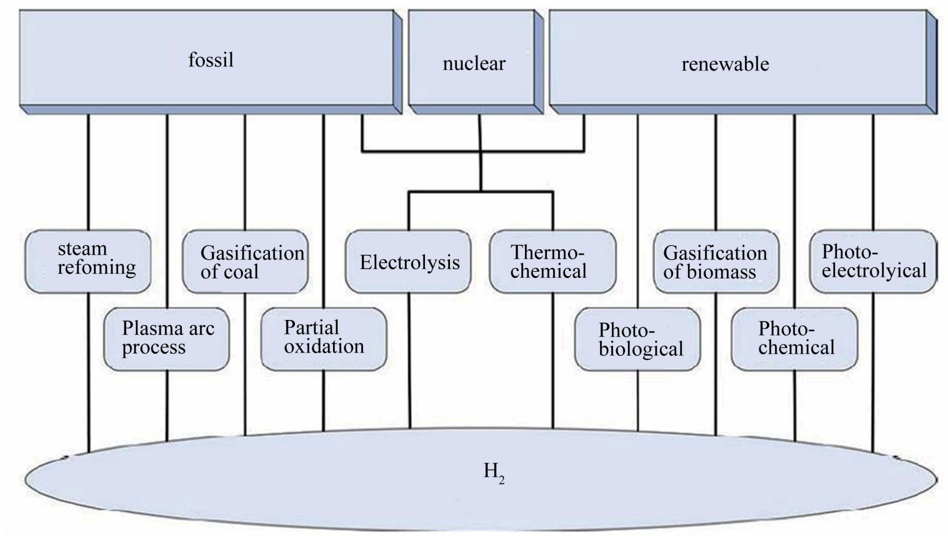

Figure 1. Hydrogen production using solar energy (photo-electrilyical).

Producing hydrogen from electrolysis with electricity at 5 cents/kWh will cost $28/million BTU—slightly less than two times the cost of hydrogen from natural gas. Note that the cost of hydrogen production from electricity is a linear function of electricity costs, so electricity at 10 cents/kWh means that hydrogen will cost $56/million BTU.

3. Description of Proposed System

The system is schematically outlined as given as shown next in **Figure 2.** The main components are:

1) Photovoltaic modules.

2) Water electrolyzer.

3) Fuel cell.

The following features are typical for the proposed system:

1) Electricity provided by the P.V. Cells is utilized for day time.

2) Electricity provided by the Fuel Cells is utilized for night time.

3) Fuel cells produce water as a by-product.

4) O_2 produced in water electrolysis could be utilized, instead of air, in the chemical reaction taking place in the fuel cell, illustrated in **Figure 3**.

The merits of our multi-purpose system are summarized as follows:

1) Supply of electricity for day use.

2) Supply of electricity for night use.

3) Availability of Hydrogen gas for energy generation using fuel cells.

4) Supply of fresh water as a by-product from the fuel cell.

5) Supply of heat source as a by-product from the fuel cell.

6) The use of the generated electricity to electrolyze sea-water to produce Hydrogen plus Sodium hypo-chlorite.

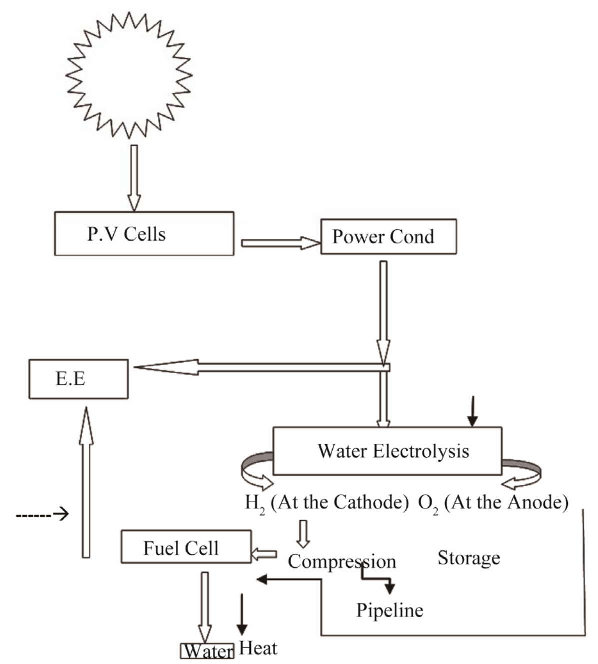

Figure 2. Schematic presentation for S.E.S.A.S.

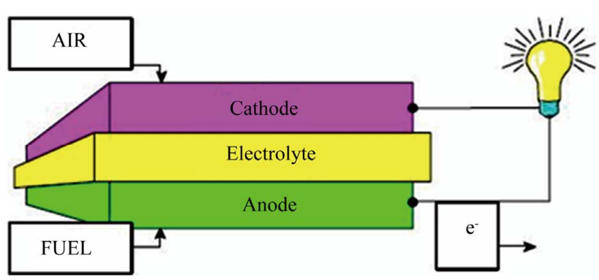

Figure 3. Function of a typical fuel cell.

The barrier to lowering the price of high purity hydrogen is the fact that it must use far more than 35 kWh of electricity to generate one kg of hydrogen gas. It takes 60 kWh to make the hydrogen itself, that's a cost of $6.00 per kg if electric power cost is 10 cents per kWh.

4. Design Parameters

The proposed study is aimed to serve a small community living on Stand-Alone Solar-Energy System (S.A.S.E.S.) [3]. As a basis for the study 1 cubic meter of hydrogen is produced by electrolysis in 5 hrs and requires energy input of 5 KW-hr.

The following are the main parameters underlying the study:

1) 2 photovoltaic modules, each is 1000 Watt (1 KW) are to be constructed.

2) One module will be used to supply electricity for day use; while the other will supply power to the hydrogen electrolyzer.

3) A 1000 Watt electrolyzer is used.

4) 1 cubic meter of hydrogen is equivalent to 3 KW-hr (thermally). For practical calculations, 5 KW-hr will be used instead of 3.

5) In one hour, 1 KW electrolyzer receives energy of 1KW-hr to produce 1/5 cubic meter of hydrogen and 1/2 this quantity of oxygen.

6) Hydrogen output will be = 7 cubic feet/hr (35.3 ft^3/m^3), as illustrated by reference [4].

7) The average annual sunshine hours for countries in the Middle East = 2500 hrs, as reported by the authors [5].

5. Economic Feasibility of the Project

To judge the economic feasibility of a project, one has to estimate first the capital investment and the operating costs. Next a life time of the equipment is assumed. Finally the production costs $/unit is figured out and compared with the current production cost of a product.

To come up with a preliminary cost for the produced hydrogen we will concern ourselves with the cost analysis for the electrolysis unit only. The following calculations are presented:

1) The annual production rate of hydrogen from electrolyzer =7 (ft^3/hr) × 2500 (hr/y) = 17,500 ft^3.

2) The capital cost of one photovoltaic module + electrolyzer = $1500 + $2500 = $4000.

3) Assuming a life time of the equipment = 10 years.

4) Annual depreciation costs = $4000/10 = $400.

5) Annual operating & maintenance costs (10% of fixed capital costs) = 0.1 ×$4000 = $400.

6) The annual total cost of hydrogen production = depreciation cost of equipment + operating and maintenance costs = $400 + $400 = $800.

7) Costs of hydrogen production= $800/(17,500 ft^3)= 5 cent/ft^3.

The cost of electricity produced by the second photovoltaic module is figured out as follows:

1) A 1000 Watt will produce energy in one year equivalent = 1000 Watt × 2500 hr = 2500 KW-hr.

2) The price of a 1000 Watt photovoltaic module is $1500. Therefore cost of electricity= ($1500)/(10 y)/(2500 KW-hr/y) = 6 cents per one KW-hr.

6. Discussions and Conclusions

The system presented in this paper offers a practical and simple mode for harnessing the sun to provide energy for a small community. Solar energy is regarded by many as the only ideal energy source especially for countries in the middle east located around the so called "solar belt". Coupling solar energy with hydrogen production along with fuel cells is the main feature of the S.E.S.A.S.

Electrolysis on the other hand is presently the most practical generation method, and offers the greatest promise of meeting required capital and operating cost objectives without requiring a major technological breakthrough [6].

Cost analysis and feasibility study indicate that the system would be more attractive for scale-up production.

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