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Future Distributed Solar Photovoltaic and Hydrogen Residence concept

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Abstract
Integrated solar photovoltaic-hydrogen system is described as the future energy solution. The distributed solar photovoltaic-hydrogen system can fulfill all the requirement of energy in any form. Solar photovoltaic alone can not satisfy the energy demand as it directly depends on solar radiation and only convert the solar energy into electricity. In true sense combination of solar photovoltaic and hydrogen system is renewable and environmentally benign as this system emits only water vapor during the combustion of hydrogen. In this concept hydrogen is not the primary source of energy but it is considered as energy carrier. Solar photovoltaic supply the electricity to the house when required and simultaneously it will supply the surplus electricity to the electrolyzer to produce hydrogen and during night or rainy day this hydrogen produces electricity by a fuel cell without any emission. The hydrogen car can also run by the hydrogen. The space required for solar photovoltaic can be solved by changing its application mode as building integrated photovoltaic system. Though there are several concept and fields on which researchers emphasizing their efforts still other new concepts are also required towards the vision of sustainable clean energy production. The objective of this review is to build the awareness of the advances towards the solution of energy crisis.
Keyword: Solar photovoltaic, hydrogen, fuel cell, hydrogen car.

Introduction

The world energy sources are limiting and it is known that the world reserves of crude oil will be over within next half century owning to the increase demands of the energy consumption [1]. Moreover fossil fuels are emitting greenhouse gases at a rapid rate that changes climate adversely. The polar ice caps and glaciers are melting at an alarming rate tending to submerge the continental masses [2]. Sea life is also under threat and investigations have stated that there would be no sea life after 2050 [3]. In order to deal with these issues it is logical to ascertain about some alternative, clean and sustainable energy sources, which will provide solution to the ever-growing energy demands. This paper discusses the integration of two important types of non-conventional and environmentally benign energy that has a very bright future: Hydrogen powered Fuel cell and Solar Energy. Direct utilization of solar energy is not a complete solution of energy in all form. Spilling of water using solar energy produces hydrogen. Hydrogen can use for generation of electricity, in IC engine, in refinery and in other industry. The limitation of hydrogen production can be solved by technical utilization of solar energy and storing solar energy in the form of hydrogen can solve limitation of solar energy application.

Fuel Cell

Fuel cells are electrochemical devices that convert chemical energy in fuels into electrical energy directly, promising power generation with high efficiency and least environmental impact [4]. Because the intermediate steps of producing heat and mechanical work, typical of most conventional power generation methods are avoided. Fuel cells are not limited by thermodynamic limitations of heat engines such as the Carnot efficiency. In addition, as hydrogen is not chemically bound with carbon unlike other gaseous fuel, fuel cells produce only water and electricity without any pollutant. However, unlike batteries the reductant and oxidant in fuel cells must be continuously replenished to allow continuous operation. Fuel cells bear significant resemblance to electrolyzers. In fact, some fuel cells operate in reverse as electrolyzers, yielding a reversible fuel cell that can be used for energy storage. Though fuel cells could, in principle, process a wide variety of fuels and oxidants, most interest today are those fuel cells that use common fuels (or their derivatives) or hydrogen as a reductant, and ambient air as the oxidant. Most fuel cell power systems comprise a number of components:

- Unit cells, in which the electrochemical reactions take place.
- Stacks, in which individual cells are modularly combined by electrically connecting the cells to form units with the desired output capacity.
- Balance of plant which comprises components that provides feed stream conditioning

(Including a fuel processor if needed), thermal management, and electric power conditioning among other ancillary and interface functions.

Fuel cells are one of the most promising means of producing energy in the future. Although they are not expected to reach the mass market before 2010, fuel cell vehicles will someday revolutionize on-road transportation. Like battery electric vehicles, fuel cell vehicles are propelled by electric motors, by creating their own electricity through a chemical process using hydrogen fuel and oxygen from the air.
The fuel cell technology offers several advantages such as enhanced efficiencies of 40 to 45 percent compared to IC engines, zero emissions as the only exhaust in a fuel cell is water vapour, and enhanced reliability compared to conventional engines. [5] But fuel cells require a constant source of hydrogen and oxygen. Today, approximately 9 million tons (~9 billion kg) of hydrogen are produced annually [6]. More than 95% of the merchant hydrogen is captive for industrial applications like chemical, metals, electronics, and space. Steam methane-reforming accounts for 80% of the hydrogen produced. The remaining 20% is a by-product of chemical processes such as chlor-alkali production. Water electrolysis represents only a niche segment of the merchant hydrogen market [6]. But in order to make this process entirely “non conventional” hydrogen has to be produced without using the fossil fuels. Electrolysis of water using solar energy is one of them.

William Grove first invented the concept of fuel cell in 1839 by combining oxygen and hydrogen to produce electricity and water [7]. After that several methods have been used to produce a fuel cell. Ludwig Mond and Charles Langer used platinum electrodes and clay barrier to produce a fuel cell. [8]. Frederick Ostwald researched and

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developed different theories based on fuel cell operation [9]. Emil Baur used different electrolytes such as molten silver and clay mixed with metal oxides to demonstrate the fuel cell [10] which was used by the British government to power submarines. Francis Bacon made a fuel cell which has nickel gauze electrodes which was used by NASA in the Apollo Space programme [11]. Henry Karl Ihrig used a fuel cell to power a tractor [12]. In the 21st century fuel cells are used in a variety of applications including home electricity, automobiles and even smaller applications like mobile phones and laptops [13]. The Indian president Dr APJ Abdul Kalam unveiled India's first fuel cell prototype car, which was been developed by REVA Electric Car Company (RECC), at the Technology Day Award ceremony at New Delhi on July 1, 2004. This car is expected to reach the showroom by 2010 [14].

Solar Cell

Our ancestors have used the sun’s heat to dry clothes and cook food. In this century it is been used to create electricity. Sun is 150 million kilometers away [15] but at every instant it sends power to the earth only if we could harness it properly. A solar cell (or a "photovoltaic" cell) is a device that converts photons from the sun (solar light) into electricity. In general, a solar cell that includes the capacity to capture both solar and nonsolar sources of light (such as photons from incandescent bulbs) is termed a photovoltaic cell. Nuclear, wind, bioenergy, and solar have positioned themselves to serve as the energy resources to produce the required hydrogen [16–19]. Among these resources, solar possesses some special attributes that may make it the power of choice in the future. The first genuine solar cell was built around 1883 by Charles Fritts, who used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold [20]. Early solar cells, however, had energy conversion efficiencies of under one percent. In 1941, the silicon solar cell was invented by Russell Ohl. In 1954, three American researchers, Gerald Pearson, Calvin Fuller and Daryl Chapin, designed a silicon solar cell capable of six percent energy conversion efficiency with direct sunlight. Bell laboratories in New York funded their research and they produced a power of 5mW [21]. In the recent decades photovoltaic cells have shown a remarkable increase in efficiency by converting nearly 40% of the photonic energy incident on them to electricity. The total peak power of installed solar panels totals 5300MW by the end of 2005 .USA, Germany and Japan accounts for 90% usage of the world solar energy [22]. Google founders: Larry Page and Sergey Brin are installing around 9200 solar panels at the 1 million square foot campus of the Google thereby expecting to get 30% of the power from the sun [23]. The total energy consumption by the world was 421 quadrillion BTU in 2003 and it is predicted to be 722 quadrillion BTU in 2030 [24]. So only solar energy from the renewable energy community and nuclear from the non renewable energy community can meet this demand [25].

The major focus herein is to look at solar PV in this application—focusing on combining the distributed-energy delivery strengths of PV with a fuel cell scheme for hydrogen and its related technologies to afford our future generations with *24-hour solar-hydrogen power.*

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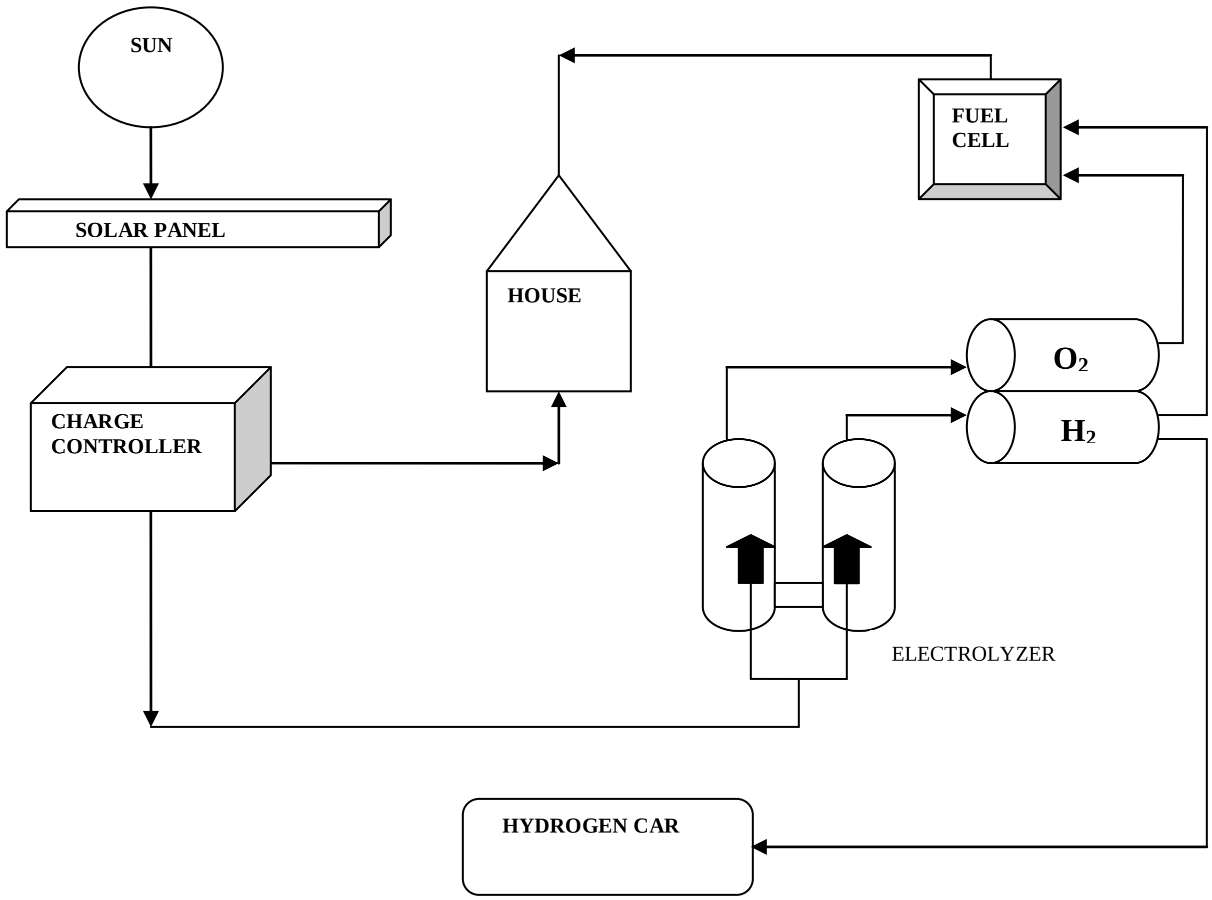

Fig 1. Concept of solar hydrogen house

For the operation of a fuel cell, continuous supply of hydrogen gas is required. Hydrogen can be produced from a number of sources like fuel reforming, natural gas, electrolysis of water etc. But producing hydrogen from the fossil fuels will not eliminate the problem of global warming and emission of green house gases. Also due to a limited availability of natural gas the problem of energy will not be solved. Hence it is not desirable to produce hydrogen from fossil fuels. Hydrogen can also be produced by the electrolysis of water as shown in the following equation:

$$H_20 = H_2 + O_2$$

The electricity required to perform electrolysis of water can be obtained from sun. India being a tropical country is blessed with lots of sunshine throughout the year. Hence solar energy can be a significant source of cheap and clean power for the future.

Thermochemical water splitting is an approach for utilization of solar energy to produce hydrogen. But these approaches will require careful handling and storage of hydrogen and long distance transportation from the electrolysis plant, which will be the most costly part of this approach.

Just as the distributed solar-PV system makes use of the economics of "electricity generation at point of use," an alternative distributed hydrogen system links "production" and "delivery" at the point of use [26]—*distributed solar electricity* and *distributed solar hydrogen.* The recent U.S. National Academy study of hydrogen provided a partial look at this approach, as well [27].

This concept can be visualized in two distinct implementations. The first phase is the installation of solar panels and photovoltaic cells at the individual residence or building [28]. The primary source of energy is the sun, which will provide solar energy that will be stored in the photovoltaic cells and convert into electricity. This solar power will be used to fulfill the electricity needs of the home and the excess of this energy will be used to perform electrolysis to produce hydrogen. This hydrogen will be the feed for the fuel cell also installed at the residence. This fuel cell can fulfill the electricity needs during night using stored hydrogen and this hydrogen can also be used to power the hydrogen car used by the family.

In the second phase the entire process is to be shared by a locality by dividing the work among them [29]. For example, some of the houses will collect solar energy, some will be involved in the electrolysis of water and some would store hydrogen. In this way the locality members will share the entire electricity produced. There would be local pumping stations to supply hydrogen to the hydrogen cars.

Merits of the project:

The greatest merit of this approach will be to the climate, since if this approach is followed by large number of homes then it will reduce the problem of global warming. Fossil fuels emit large amount of carbon dioxide which is responsible for global warming. Moreover sulphur dioxide is also emitted which is highly corrosive and harmful for our eyes and skin. But in fuel cell the end product is only water. Solar distributed hydrogen concept is the complete solution for all the problems of earth's atmosphere.

Is Hydrogen Safe!

In many ways, hydrogen is a good deal safer than gasoline or diesel. Like any fuel, hydrogen stores significant amounts of energy, and handling it requires certain safety precautions. But hydrogen can be safer than gasoline if it is used properly. Because it is so light, hydrogen disperses and floats skyward when leaked—it won't pool or soak into clothing like gasoline, just waiting to ignite. (Spilled hydrogen won't soak into the earth and pollute ground water either, or cause an environmental disaster like the Exxon Valdez).

But what if the hydrogen does somehow ignite in a car? Tests conducted at the College of Engineering at Miami University aimed to find this out. 3000 cubic feet per minute of hydrogen was leaked from a vehicle tank and set alight. Over the course of the burn, temperature sensors inside the vehicle did not measure an increase of more than 1 or 2 degrees centigrade anywhere inside the vehicle. The temperature of the surface of the outside of the vehicle did not climb above that of a vehicle sitting in the sunshine!

This might sound unintuitive. But when a carbon-based fuel like gasoline burns, glowing hot soot particles transfer the heat to its surroundings—potentially including you. But because hydrogen contains no carbon, it burns cleanly without a residue of hot soot, producing little radiant energy. This means that a victim would have to be practically in the flame in order to get burned.

Pressurized hydrogen tanks are made to withstand enormous impacts. Some fear that a hydrogen tank has the potential to explode, and that is possible. But these critics often overlook the greater explosive potential of the CNG tanks in their very own cars.

Many real-life tests have demonstrated the safety of pressurized hydrogen storage. Simulated 55 mph crash tests left the car totaled, but the hydrogen tank intact. To prove the safety of its hydrogen vehicles, BMW tested its hydrogen tanks in a series of accident simulations that included collision, fire and tank ruptures. In all cases, the hydrogen cars fared as well as conventional gasoline vehicles. And hydrogen-fueled cars are designed to preclude the possibility of leaked hydrogen collecting within the vehicle.

The *Hindenburg Myth*

Most hydrogen concerns stem from the Hindenburg disaster of 1937. The hydrogen gas that once filled the Hindenburg zeppelin did burn, but it did so quickly, upwardly, and away from the people below. When the airship was docking, an unexpected electrical discharge ignited the airship's canvas (which was unknowingly treated with two major components of rocket fuel!) The clean hydrogen flames swirled above the occupants of the passenger compartment, and all those who rode the airship down to the ground survived. 35 of the 37 casualties perished from jumping to the ground, and most other injuries resulted from diesel burns. [30]

Conclusion:

Development of energy sufficient residence through extensive research may solve most of our major problems due to its sustainability, cleanliness and distributed in nature. The main drawbacks are the cost of PV cell, development of reliable fuel cell and efficient hydrogen storage system. Researchers can play a vital role by spreading the awareness as well as the efforts on the different limitations of the sustainable, clean and cheap energy production.

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