

Solar hydrogen/ fuel cell hybrid energy system for vehicles: The Green Energy

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Abstract

Solar-hydrogen is a completely Green system which avails all the Energy requirements using a Hybrid System that employs photovoltaic (PV) panels to convert sunlight into electricity which is used for home appliance in the day time and remaining Electricity that is harnessed to extract hydrogen from harvested rain water or tap water. There is a focus on working of this system. This paper examines the technology, environmental impacts, safety, and economics of solar-hydrogen energy. It also describes the generator of green energy.

Keywords: Fuel cell, Solar PV, Inverter, water, Output Voltage Regulation, equivalent circuit

1. Introduction

Solar hybrid systems are composed of solar, electrolyser, fuel cells, battery, hydrogen storage systems and the necessary converters. The hybrid energy system consists of array of solar panels on the roof, fuel cells system for night time power supply and a small electrolyser. An electrolyser is a device of size smaller than that of a washing machine that uses electricity to break down water into its component hydrogen and oxygen. It requires a few tanks to store hydrogen, Plug Power fuel cell stack and a hydrogen refuelling kit for the car. Hydrogen that is extracted from water using solar energy is sustainable and renewable energy. Power fuel cell stack is an electrochemical device that mixes hydrogen and oxygen to produce electricity and

water.

On a sunny day, the solar panels convert sunlight to electricity; a part of electricity will be consumed to run the home appliances, including television and other modern conveniences. The remaining electricity used for the electrolyser, which splits the molecules of purified water into hydrogen and oxygen. The oxygen is vented and the hydrogen goes into the tanks where it is stored for use in the fuel cell to provide electricity for the house during night and also the stored hydrogen will be used to full fill energy requirement in the cold and dark winter months from November to March when there are few days sunshine per months. This system produce only water as a waste product, which can be pumped right back into the system.

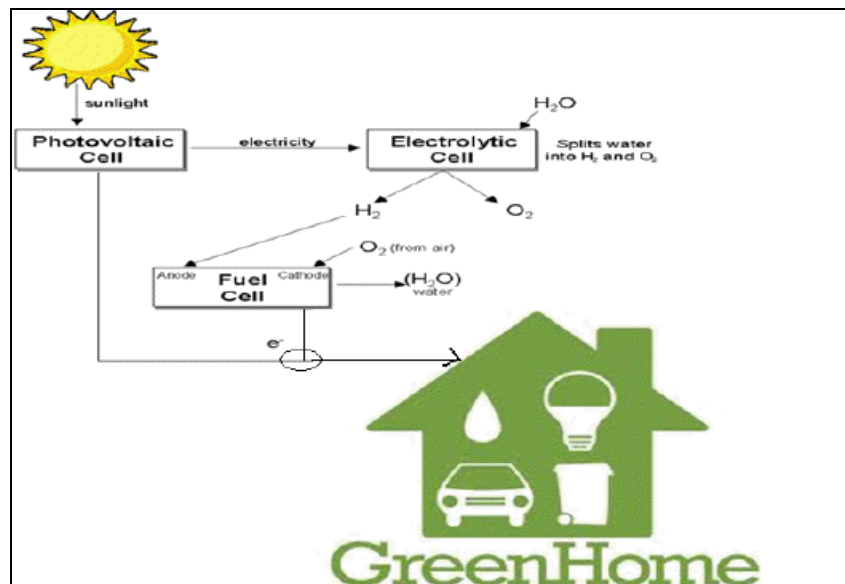


Fig 1

The strategy to setup this system equipped with hybrid solar hydrogen system & rain water harvesting system is to create a new lifestyle which is convenient, clean, energy- efficient and sustainable. The combination of a fuel cell electric vehicle and the hybrid solar hydrogen system will lead to

the establishment of a hydrogen society based on renewable energy. It results in a major reduction of CO₂ emissions and greater saving of energy and hence environmental sustainability.

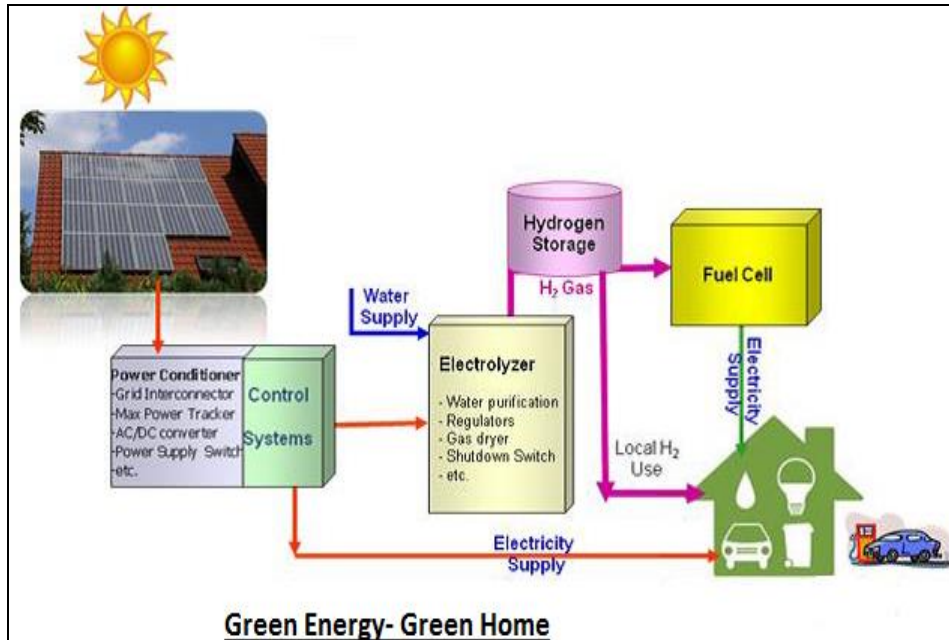
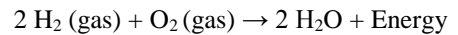


Fig 2

1.1 Fuel Cell

A fuel cell is an electrical cell, which unlike storage cells can be continuously fed with a fuel so that the electrical power output is sustained indefinitely (Connihan, 1981). They convert hydrogen, or fuels containing hydrogen, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse.



Since hydrogen & oxygen gases are electrochemically converted into water, therefore fuel cells have many advantages over heat engines. These include high efficiency, virtually silent operation and, if hydrogen is the fuel, there are no pollutant emissions. If the hydrogen is produced from renewable sources of energy, then the electrical power produced can be sustainable.

1.2 Overall reaction

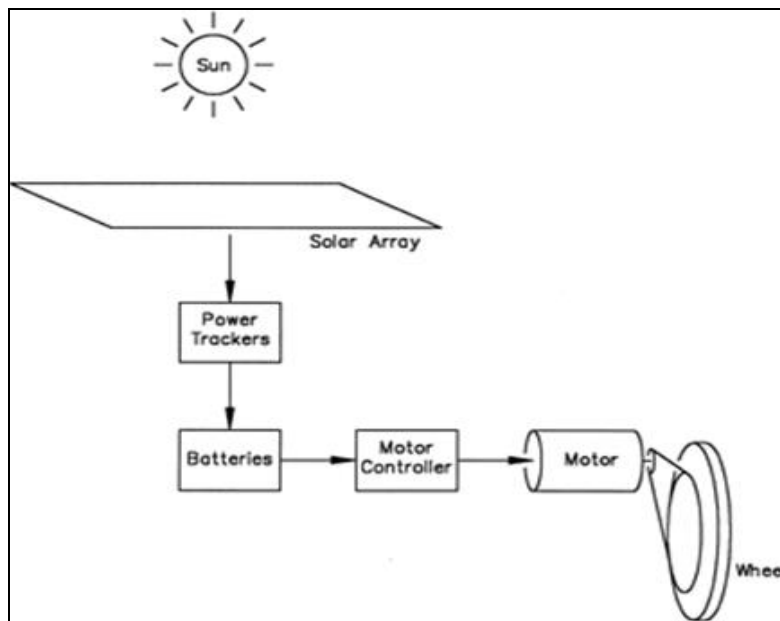


Fig 3

The two principle reactions in the burning of any hydrocarbon fuel are the formation of water & CO₂. As hydrogen content increases, fuel becomes proportionally dioxide. As fuel use has developed through hydrogen content in the fuels has set. It seems a natural progression that the fuel of the future will be 100% hydrogen.

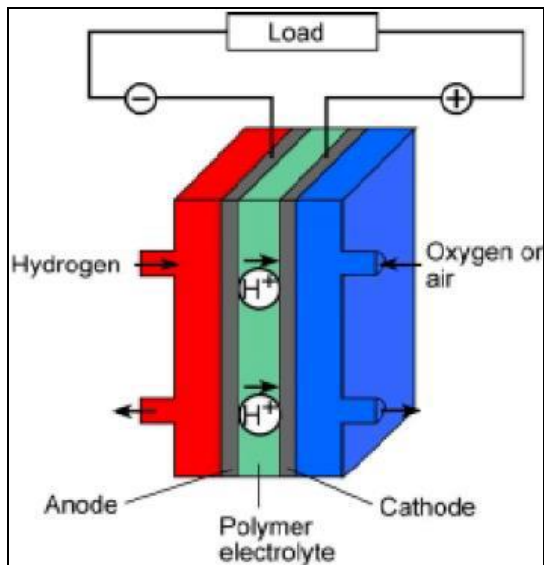


Fig 4

1.3 Working of System

Hydrogen & oxygen will be produced from water using electricity with an electrolyser. With the installation & operation of Hydrogen cells & high power electrolyser, this electrolyser can produce hydrogen and oxygen at standard temperature & pressure. We can describe a homebrew purification & storage system for the hydrogen & oxygen produced by the electrolyser. With proper after-treatment, the gases produced can be stored safely. The purified hydrogen & oxygen can be used in fuel cells to produce the direct current electricity and catalytic burners for heating and cooking without poisoning or damaging the noble metal catalyst materials. The gases can also be used for welding, cutting and for motor vehicle fuel.

1.4 How Much Hydrogen is needed?

Hydrogen is an especially attractive transportation fuel. It is the least polluting fuel available, and can be produced anywhere there is water and a clean source of electricity. A fuel cycle in which hydrogen is produced by solar-electrolysis of water, or by gasification of renewably grown biomass, and then used in a fuel-cell powered electric-motor vehicle (FCEV), would produce little or no local, regional or global pollution. Also this varies tremendously from household to household, depending on how well the Demand Side Management job has been done. We can run 1kW system for about three hours on a cubic meter of

hydrogen. The amount of gas needed can be estimated from the energy consumption of any appliance.

1.5 How Much Power Does It Take?

A cubic meter (35.3 cubic feet) of hydrogen gas takes about 5.9 hours to produce in this electrolyser, and then operated at its rated input power of 1 KW. This means the energy required producing a cubic meter of hydrogen and 0.5 cubic meter of oxygen is about 5.9 kW-hr. This translates to an efficiency of 51%, where 3 kW-hr/m³ equal to 100% efficiency at 20°C. Typical industrial scale plants operate at about 4.5 kW-hr/m³ or 67% efficiency at high current density. The efficiency is better at lower current density.

1.6 How much Power required for the Electrolysis?

Solar electric power is produced by 10 photovoltaic solar panels. On a sunny day, we may get up to 75 Amperes at 24 Volts Direct Current. This can be supplied for home appliance by converting and stepping up by Inverter or when the two house battery banks are fully charged. An automatic controller senses the voltage rise and transfers the PV power to the electrolysers to make hydrogen and oxygen during the remaining day. A utility grid electrolyser power supply is used to make hydrogen and oxygen when there is insufficient solar power available.

The hydrogen gas and the oxygen gas are then purified by two different systems. The hydrogen will be stored in a propane tank, and the oxygen will be stored in another propane tank.

1.7 Components of the hybrid system:

- Solar PV module/or utility grid power
- Power Controller
- Electrolyser and PEM Fuel Cell
- Hydrogen Purifier
- Hydrogen and Oxygen Storage Tanks
- Electrolyte Storage Tank and Transfer Pump
- Makeup-water Purifier

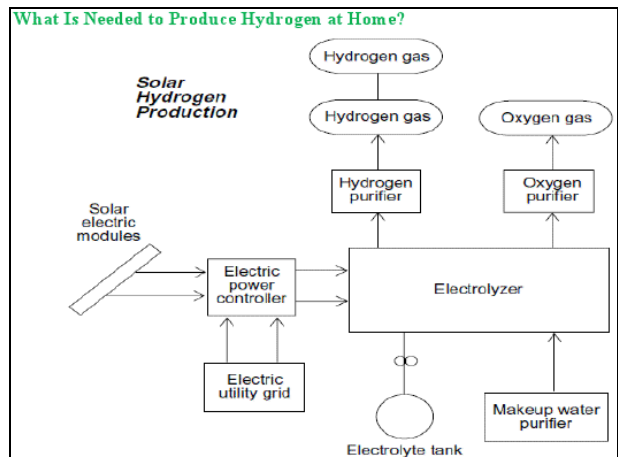


Fig 5

1.8 Technology used in Hybrid System

Fuel cells and electrolyzers are the complementary technologies. An electrolyzer cell is much like a fuel cell run in reverse, using electricity instead of producing it. Commercial electrolyzer technology is widely available and includes both proton exchange membrane and alkaline electrolyzers.

As pure hydrogen is the fuel produced, any type of fuel cell can be used to convert this into electricity in stationary power generation. For fuel cell vehicles, the technology of choice is proton exchange membrane fuel cells (PEMFC).

1.9 Generators of Green Energy

Only a few of Green Energy generators were making electricity before Green Energy was set up in UK. The company's generators are all approved by of gem and have a large range of sources including energy from waste, biomass, solar/PV, small scale hydro, wind, combined heat and power and anaerobic digestion.

The company only buys green sourced electricity and has no brown energy or nuclear in its business. Green Energy facilitates investment into renewable technologies by creating demand for this green electricity.

1.10 Advantages

- Applicability for distributed power generation: power is generated at the site where it is used rather than central generation and distribution through a grid. On site generation avoids transmission line losses of 98% to 100%.
- Low maintenance and reduced down time: This systems require low or negligible maintenance and can achieve 99% availability.
- Off-grid independence: Brownouts and blackouts associated with distribution grids are eliminated by onsite generation. This system provides a useful online backup where uninterruptible power is needed.
- Quality of electricity: Constant flow of current with few fluctuations—important for many scientific and technological applications.
- Environmentally benign: Hydrogen fuel cells have only water as an emission.
- Energy independence: This System provides grid-independent electric power and reduces dependence on oil imports for India.
- Lack of noise: Fuel cells are quiet.
- Efficiency: Fuel cells are more efficient than most fossil fuel power plants and internal combustion engines as well as battery.
- Lighter and longer life: For portable applications, fuel cells are lighter and have a longer run time than batteries, and when they do run out of fuel they don't require a long, inefficient recharging process, only refuelling.

1.11 Analysis of Social, Economic & Environmental Impact

In the general social and economic contexts, energy systems form an integral part of the society. Seen from that perspective, their planning and implementation should be performed accordingly. The availability of energy is a basic requirement for most tasks in a modern society, both in the domestic life and for the business, commerce and the service sectors.

This system produced and consumed in a clean and sustainable manner, offering important environmental benefits (CO₂ and other pollutants reduction, which helps to fulfil the international agreements on limits for emissions). Electricity generation from this system offers socio-economic benefits from untapped solar energy and rain harvesting water.

This project supports the decentralization of energy production that does not rely upon constrained transmission and distribution grids and offers a steady and secure supply of energy. Our system is strongly supportive of country policy in areas such as, meeting energy requirement, major reduction of CO₂ emissions and greater energy savings and environmental sustainability. The use of our system gives value to the society in betterment of lifestyle of citizen.

The way in which the social value depends on the economic environmental relation is depicted. It is easy to understand that the higher the environmental and economic values are, the higher the social value will be. When the economic and environmental values rise together, then the social welfare value rises as well, as a result of the high appreciation given to both the other factors. The social value moves through three different zones- of low, medium and high social values.

2. Conclusion

As the demand for electrical power grows, it becomes increasingly urgent to find new ways of meeting it both responsibly and safely. In the past, the limiting factors of renewable energy have been the storage and transport of that energy. With the use of fuel cells and hydrogen technology, electrical power from renewable energy sources can be delivered where and when required, cleanly, efficiently and sustainably.

3. References

1. Nehrir H, Caisheng Wang, Shaw SR. Fuel cells: promising devices for distributed generation, IEEE Power and Energy Magazine 2006; 4(1):47-53.
2. Caisheng Wang, Hashem Nehrir, Steven R Shaw. Dynamic Models and Model Validation for PEM Fuel Cells Using Electrical Circuits, IEEE Trans Energy Conversion, 2005, 20(2).
3. Maclay JD, Brouwer J, Samuelsen GS. Dynamic modeling of hybrid energy storage systems coupled to photovoltaic generation in residential applications Power Sources 2007; 163:916-25.

4. Mann RF, Amphlett JC, Hooper MAI, Jensen HM, Peppley BA, Roberge PR. Development and application of a generalised steady-state electrochemical model for a PEM fuel cell, *J Power Sources* 2000; 86(1-2):173-180.
5. El-Sharkh MY, Rahman A, Alam MS, Byrne PC, Sakla AA, Thomas T. A dynamic model for a stand-alone PEM fuel cell power plant for residential applications”, *J Power Sources*. 2004; 138(1-2):199-204.
6. Zhong Zhi-dan, Huo Hai-bo, Zhu Xin-jian, Cao Guang-YI. Ren Yuan Adaptive maximum power point tracking control of fuel cell power plants *J Power Sources*. 2008; 176:259-269.
7. Hussein K, Muta I, Hoshino T, Osakada M. Maximum Photovoltaic Power Tracking: An Algorithm for Rapidly Changing Atmospheric Conditions, *IEE Proc. - Generation, Transmission, Distribution* 1995; 142(1):59-64.
8. Maggio G, Recupero V, Pino L. Modeling Polymer Electrolyte Fuel Cells: An Innovative Approach, *Journal of Power Source*. 2001; 101:257-286
9. Lukas MD, Lee KY, HG. An Explicit Model for Direct Reforming Carbonate Fuel Cell Stack *IEEE Transactions on Energy Conversion* 2001; 16(3):289-295.
10. Correa JM, Farret FA, Canha LN. An Analysis of the Dynamic Performance of Proton Exchange Membrane Fuel Cells Using an Electrochemical Model *IECON'01*, 2001, 141-146.
11. Kelouwani S, Agbossou K, Chahine R. Model for an energy conversion in renewable energy system with hydrogen storage, *J Power Sources*. 2005; 140(2):392-399.
12. YunHai-Tao, Zhao Yulan, Wang Jizhong. modeling and simulation of Fuel cell hybrid vehicle. *System Simulation* □ In Chinese □
13. Pedrazzi S, Zini G, Tartarini P. Complete modelling and software implementation of a virtual solar hydrogen hybrid system, *Energy Conversion and Management* 2010; 51:122-129.
14. Gabriele Zini, Riccardo Marazzi, Simone Pedrazzi, Paolo Tartarini. A solar hydrogen hybrid system with activated carbon storage. *International journal of Hydrogen Energy*, 2009, 1-9
15. Uzunoglu M, Onar OC, Alam MS. Modeling, control and simulation of a PV/FC/UC based hybrid power generation system for stand-alone applications. *Renewable Energy* 2009; 34:509-520.