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Optimizing Fuel Cells in Energy Storage Technologies for Renewable Energy Sources

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ABSTRACT
The prime objective of this work is to optimize the fuel cells to improve its utilization with continuous power generation. Fuel Cell will dominate among the energy storage devices shortly and it is the top technical challenge in the present scenario. The hydrogen gas is fed as an input to the anode and oxygen is supplied across the cathode of the fuel cell is in vogue. This work contributes to saving of hydrogen gas through recycling process of the fuel cell. The fuel cell incorporates steam reforming methods to separate hydrogen and carbon monoxide ions. Steam reforming process results with hydrogen in liquid form; however only gas form is essential for anode terminals of the fuel cell, hence using liquid to gas conversion process is essential. The process of converting hydrogen liquid to gas is obtained using cryogenic separation. This process includes recycling methods to generate electrical power without any loss of time. This proposed fuel cell reduces the hydrogen fuel requirement and this, in turn, improves the nation economy, and it can also be used in hybrid battery operated vehicles. This paper presents a current state-of-the-art in fuel cells which offers a clear vision of the latest research advances in energy storage technologies.
Keywords - Fuel cells, Electrolysis, Battery, Hydrogen, Oxygen, Renewable Energy.

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I. INTRODUCTION

Fuel Cells will act as the life blood in the alternate sources of electrical energy within 2020. Germany and other countries could deploy energy storage more efficiently with the aid of advanced reliable energy storage technologies and strategies [1]. This can also be possible in India by, appropriate design and analysis of fuel cell and enabling the fuel optimization as high as 98% and above[5]. Irrespective of the source, a more effective storage system is very critical for the efficient use of the energy [6-7]. The electrode materials for energy conversion systems; including ionic conducting materials for intermediate temperature fuel cell systems, through characterization of the novel materials aids the fabrication of fuel cells commercially [8].

In developing countries like India, most of the rural areas have no access to electricity due to the uneconomical grid extension and non-availability of energy sources [9-10]. Energy demand is floating with the increase in population, decreased energy production increase in fuel cost, etc. In earlier 1971s, due to the oil crisis, a tremendous interest have been showed towards the utilization of renewable energy sources for supplying the energy to the remote areas and also to the places where there is abundant of natural energy resources [11].

Among the various energy sources, solar and wind energies, cogeneration is most widely used and predominant [2]. The main disadvantages of these two resources are intermittent nature, site-specific, seasonally dependent, etc. and so on. Some of the other energy sources used for electricity production are water, biomass, biogas, geothermal heat, etc.[14] Usually, renewable energy systems are based on single energy sources or multiple energy sources[3-4]. Single energy source based systems utilize one source based on solar/wind/biomass/biogas based on their availability, whereas multiple energy source based systems incorporate more than one energy sources along with the battery and a suitable power electronics and drives systems for the power conversion [15].

The development and use of fuel cells have experienced rapid growth over the past decades. However, these sources do not deliver a regular supply easily adjustable to consumption needs. Thus, the need of study of energy storage in fuel cells, as a potential solution. However, different types of fuel cells have different types of electrode such as Direct

Methanol Fuel Cell (DMFC), Hydrogen Fueled Fuel Cell, Borohydride Fuel Cell, PEM Fuel Cell, Nanomaterial-based fuel cell in which the discharge of energy can be varied with respect to time. Unlike a battery, chemicals are not stored in the fuel cell; they must be replenished Possible fuel sources: hydrogen, alcohols, hydrocarbons, gasoline Possible oxidants: oxygen, chlorine, chlorine dioxide. The basic fuel cell block diagram is shown in figure 1.

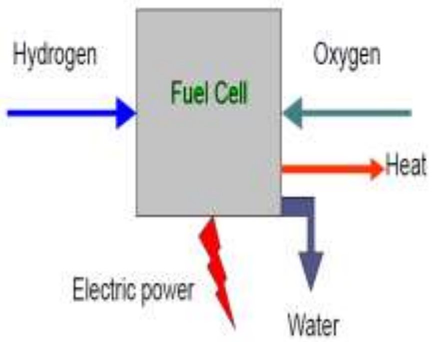
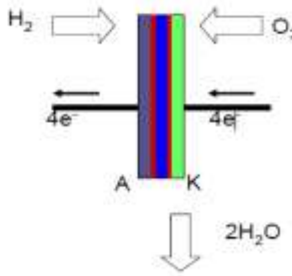


Fig. 1.Elimentary fuel cell

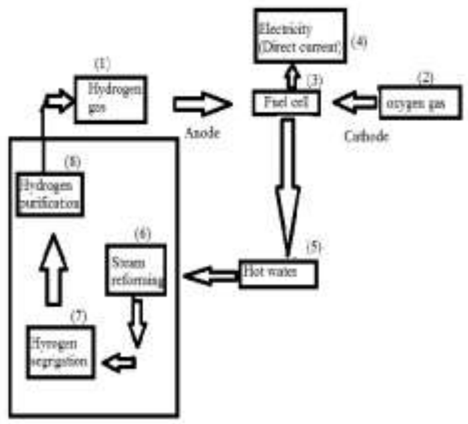


A = Anode, K = Cathode
Fig. 2 Net reaction

II. MATERIAL AND METHODS

When H2 molecule comes in contact with platinum catalyst, it splits into two H+ ions and two electrons (e-). Electrons conducts through the anode make their way through the external circuit and return to the cathode side of the fuel cell a shown in figure 3. On the cathode side, oxygen gas (O2) is forced through the catalyst, which results in the form of two oxygen atoms, each with a strong negative charge. Negative charge attracts the two H+ ions through the membrane and combines with oxygen atom with two electrons from the external circuit connected to form a water molecule (H2o). Anode and Cathode on each side of the fuel cells, divided by an electrolyte produces direct current. Hydrogen gas is channeled through anode side; oxygen passes through cathode. Platinum catalyst oxidizes hydrogen atoms into H+ and electrons. Electrons pass along with an external circuit; conduct electricity before entering the cathode. Electrolyte allows H+ to pass into the cathode. Across the cathode end, the catalyst combines H+ , O2- and electrons, forming water and heat.

Platinum is the primary catalyst used in PEM fuel cells. Platinum is expensive and highly sensitive to poisoning. New platinum/ruthenium catalysts being researched for use in hydrogen fuel cells. The intelligent fuel cell is using recycling method, contrary to the conventional electrolysis process. In the steam reforming process, the hydrogen and oxygen are segregated from the output of fuel cell. Subsequently, the hydrogen liquid is converted to its corresponding gas form Cryogenic process and is subjected to the purification process. Later, after purification pure recycled hydrogen gas is fed as an input to the anode of the anode fuel cell as shown in figure 3.



Recycling Process
Fig. 3 Block diagram of recycling fuel cell

2H2 + O2 →2H2O (1)
Anode: 2H2 →4H++4e- (2)
Cathode: O2+ 4H++ 4e- →2 (3)

2.1 Electrolysis process

Electrolysis process is hydrogen production demands high amounts of energy and is very insufficient. A lot of the energy consumed to separate the hydrogen and oxygen through electrolysis and is lost in the form of heat. The conventional electrolysis process is shown in figure 4.

$2H_2O(l)\rightarrow 2H_2(g)+O_2(g)$ (4)

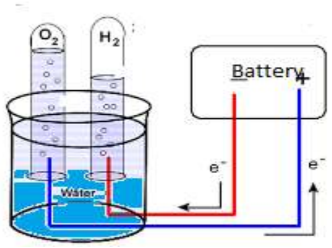


Figure 4 Electrolysis process

2.2 Optimizing Fuel cell

Optimizing fuel cell is obtained by using a conventional fuel cell along with recycling process. This fuel cell consists of hydrogen (anode), oxygen gas (cathode) with electrolyte. The output of the fuel cell is a direct current along with a finite temperature of water.

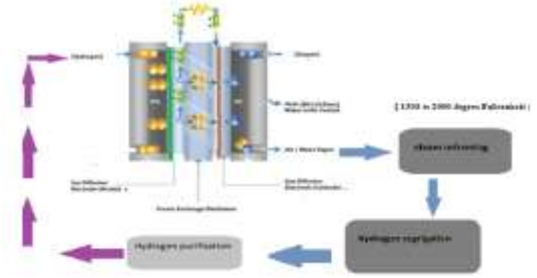


Fig. 5 Optimizing fuel cell using steam reforming

The fuel cell consists of steam reforming steam reforming method which is the cheapest method of unraveling hydrogen from water. This process encompasses high temperature ranging from 1300 to 2000 degree Fahrenheit. At such high temperatures water vapor react with natural gas (methane) resulting with hydrogen and carbon monoxide. Steam reforming process results with hydrogen liquid. Perhaps, hydrogen gas is essential for the smooth operation of fuel cells, which is obtained using Cryogenic process. This results with continuous generation of electrical power as shown in figure 5. This reduces the hydrogen fuel and finds applications in renewable energy resources.

$$CH_4 + H_2O \ (+ \text{heat}) \rightarrow CO + 3H_2 \qquad (5)$$

1.3 Energy Conservation using Fuel Cell

The energy conservation is achieved using hydrogen-oxygen based fuel cell. The output of the fuel cell which is in terms of dc voltage is given to a chopper circuit. The dc-dc converter converts the 12v dc to 220v dc supply which converts the 220v dc to 400v ac supply. Boost converter based PFC has been a trend as it has the design that would eliminate the second order harmonics in the supply side [15].

The output of the inverter is given to a transformer for synchronizing the on line grid profile. The block diagram of the energy conservation system is shown in figure 6.

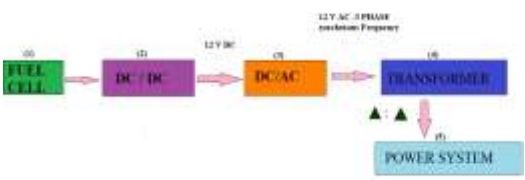


Fig. 6 A typical Energy conservation system using fuel cells

III. RESULTS AND DISCUSSION

The results which are obtained from the work done are discussed below. The steam reforming based fuel cell output efficiency is compared with electrolysis process based fuel cell. The output efficiency of electrolysis and fuel cell is shown figure 6 and 7 respectively. The electrolysis process based fuel cell efficiency initially increase and later it saturates and output curve becomes non-linear. The steam reforming based fuel cell output efficiency is increases linearly as shown in figure 7.

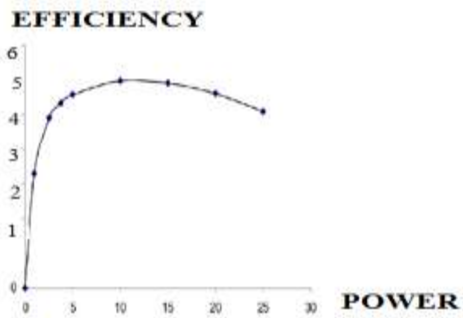


Fig. 7 Output efficiency of electrolysis process

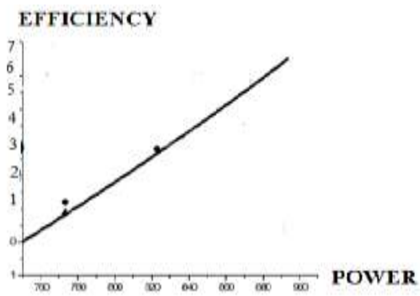


Fig. 8 Output efficiency in fuel cell

The converter is aimed to handle a wide range of input voltages and efficiently convert the unstable electrical voltage generated by a fuel cell into usable power for equipment operating on DC shown in figure 8.

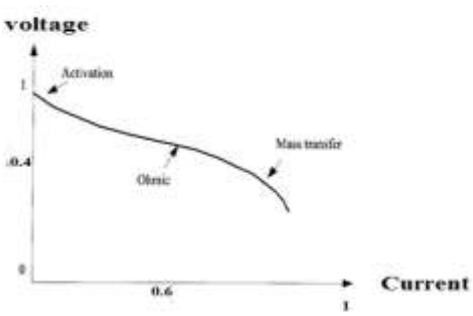


Fig. 9 Characteristic of a fuel cell

The novel prototype model optimizing fuel cell is shown in figure 10, which shows the interconnected steam reforming and hydrogen purification. One of the primary objectives is to reduce the utilization from the hydrogen h input. For this various filtering methodology are being adopted which shows the output obtained after filtering the gas supply to the anode and fuel cell using energy conservation process. Due to involve many number of power electronics converter.

Fig. 10 Protype model of Stack of fuel cell

Process	**Recycling**	**Characteristics**	**Hydrogen production**	
Electrolysis	Not applicable	Non-linear	58%	50 %
Steam Reforming	Simple and straight forward	Linear	72%	70 %

Table 1 Trade-off between Electrolysis and Fuel Cell

IV. CONCLUSION

This paper presents a novel fuel cell, which is based on the concept of conversion of chemical energy into electrical energy. This aids the present electricity demand and paves a way to reduce the hydrogen fuel requirement. However, to tune the gain of the steam reforming is a challenging task. Thus, this proposed method incorporates recycling process of hydrogen and ultimately reduces the hydrogen fuel requirement and generated cost-effective continuous electrical power. Hence, the hydrogen recycling has opens new research avenues when compared to wind, solar and biological form of power generation. However, advances with lower-cost materials, dye-sensitization, catalysts and novel system conjurations are bringing this technology much closer to commercial practicality and prime motive of the optimizing fuel cell not create in any form toxic waste, other pollutions.

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