FUTURISTIC FUEL CELLS

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Abstract:

To create a worldwide hydrogen (H_2) economy with fuel cells providing clean, safe Electrical energy, end users will have to embrace this energy carrier. That means using it onboard their vehicles, at fueling stations in their neighborhoods, in their electronic devices such as cell phones and laptop, computers as well as in stationary installations providing electricity for homes and businesses. H_2 -powered fuel cells that provide backup power for hospitals, banks, and telecommunications during grid "brown outs" or "black outs" have endeared the public to this new technology in the short term. However, despite field tests to establish proof of performance with customers, and industry efforts to establish fuel cells as a viable method of power production in the long term.

Basic Principles Of Fuel Cells :

A fuel cell is an electrochemical cell but it differs from a traditional battery in several ways. A battery is a energy storage device in which the amount of electrical energy available is dependent on the mass of the chemical reactant stored in the battery. When the reactants are fully consumed [discharged], the battery must be recharged before it can be used again . But a fuel cell is an energy conversion device , which is able to produce electricity as long as reactants are provided. Because a fuel cell transforms the fuel directly to electricity without combustion, there is little waste heat and the rate of chemical to electrical energy conversion is very high. Thus a fuel cell operates as long as fuel and air are available.

Hydrogen is an excellent fuel because it produces only water, which does not adversely affect the natural environment. The first H_2 / O_2 fuel cell containing dilute sulphuric acid as electrolyte was demonstrated in 1839 by W.R. Grove at the Royal Institution, London. The Primitive cell consisted of two Platinum strips surrounded by closed tubes containing H_2 and O_2 respectively, formed by preliminary electrolysis of the electrolyte .The report by Jacques in 1896 on a 1.5 kW direct coal based fuel cell is perhaps of interest . Molten KOH at 400-500 degree C was contained in iron vessels serving as cathodes. A carbon rod served as the anode with air blown in at the bottom of the cell. With 100 cells in series, a current density of 100mA/sq.cm at 1.0 V was realized. Hydrocarbon containing fuels rich in hydrogen such as coal, biomass, ethanol, methanol, methane and propane can also be used. Hydrogen is produced from these by means of a reforming reaction, carried out either externally or internally. In a fuel cell operated at high temperatures (e.g. molten carbonate fuel cell) the heat is used for generating H_2 and CO_2 as well as facilitating electrode reactions simultaneously.

In a low temperature fuel cell, the reforming process occurs in an external reformer and the hydrogen produced is consumed to generate electricity.

If natural gas has to be used, it is processed in a reformer to create hydrogen rich fuel. The processed fuel is then fed to the fuel cell between the end plate (or bipolar separator plate) and the anode. Simultaneously, air (oxygen) is cleaned with filters and then channeled between the cathode and bipolar separator plate (or end plate). Sandwiched in between the anode and the cathode are the electrolyte matrix. This porous material enables the hydrogen and oxygen to chemically react. Electrode reactions occur releasing free electrons that flow along an external circuit, through anode and to the cathode. This process takes place in each fuel cell. Multiple cells are arranged in "stack" to produce high voltage.

Benefits of Fuel Cells:

1. **Zero emission and quieter operation :**

Fuel cells are developed with the concept of "Zero emission" technology. Theoretically they emit only steam and heat as byproduct. Fuel Cell Vehicles (FCV) powered by pure hydrogen emits no greenhouse gases. If the hydrogen is generated by reforming fossil fuels, some greenhouse gases are released, but much less than the amount produced by conventional vehicles. Highway vehicles account for a significant share of the air pollutants that contribute to smog and harmful particulates. FCVs powered by pure hydrogen emit no harmful pollutants. FCVs that use a reformer to convert fuels such as natural gas, methanol, or gasoline to hydrogen do emit small amounts of air pollutants such as carbon monoxide (CO). According to the presently available data the emission levels are: NO_x - less than 0.5 ppm, SO_x - zero, CO - zero, CO_2 - lowest, because inversely proportional to the high efficiencies[1]. Moreover due to the absence of any moving parts to generate power, Fuel cell vehicles are much quieter than internal combustion engines although wind and road noise will still be present at higher speeds.

2. **More Energy Efficient:**

Fuel cell systems produce electrical energy at very high efficiency. Internal combustion engines in automobiles convert less than 20% of the energy in gasoline into power that moves the vehicle. Vehicles using electric motors powered by hydrogen fuel cells are much more energy efficient, utilizing 40-60% of the fuel's energy. Even FCVs that reform hydrogen from gasoline can use about 40% of the energy in the gasoline. Only large combined cycle power plants can outperform fuel cells. However, if high electrical efficiency is required, fuel cells can be combined with gas turbines, thereby surpassing the efficiency of combined cycle systems, while maintaining zero emission characteristics. Due to the ability to integrate power production in dwelling areas, efficient use of the waste heat is possible.

3. **Fuel diversification and National energy security:**

At present, the energy source for transport is oil. Fuel cells prefer hydrogen, which can be derived from many sources, such as methanol, natural gas, and gasoline, as well as renewable resources such as water, biomass and from electricity derived from e.g. wind and solar energy. These will very like be the energy sources of the future. Thus, fuel cells help to reduce the dependence of oil, and enable the transition to a sustainable energy system. This flexibility would also make us less dependent upon oil from foreign countries.

4. **Design Flexibility:**

The use of fuel cell stacks and electric motors affords automobile manufacturers a great deal of flexibility in designing vehicles. Fuel cell systems can be designed to fit almost any shape or body style. Also FCVs can be equipped with more sophisticated and powerful electronic systems than those found in conventional gasoline vehicles. For example, some vehicle manufacturers are designing vehicles that use electronic steering and braking. Eliminating the steering column and wheel may make these vehicles safer.

Types of Fuel Cell :

Depending on the type of electrolyte used, fuel cells are generally classified into five major categories:

1. Alkaline Fuel Cells - AFC
2. Phosphoric Acid Fuel Cells - PAFC
3. Molten Carbonate Fuel Cells - MCFC
4. Solid Oxide Fuel Cells - SOFC
5. Direct Methanol Fuel Cells - DMFC
6. Proton Exchange Membrane Fuel Cell- PEM
7. Regenerative fuel cells- RFC

Here, we will discuss only about regenerative fuel cells- RFC. Still a very young member of the fuel cell family, regenerative fuel cells would be attractive as a closed-loop form of power generation. Water is separated into hydrogen and oxygen by a solar-powered electrolyser. The hydrogen and oxygen are fed into the fuel cell which generates electricity, heat and water. The water is then recirculated back to the solar-powered electrolyser and the process begins again. These types of fuel cells are currently being researched by NASA and others worldwide.

Complex safety issues with vehicles:

Though FCVs represent one of the potential high volume markets, transportation application of fuel cells still appears to have the longest timeline to commercialization (at least the year 2020 by some estimation). They also require perhaps the most complex integration of a fuel cell system. As described by the California Fuel Cell Partnership (CaFCP), "a fuel cell engine is the complete set of components that integrate with a fuel cell to form a small energy plant that creates electricity to power a vehicle's wheels." The well known benefits of H_2 powered FCVs boil down to near zero pollution, except for exhaust water vapor, and zero production of greenhouse gases due to a lack of combustion and increased energy efficiencies. FCVs can also contribute to reducing noise pollution. FCVs could be used as backup power systems for residential or business electricity. CaFCP identifies four major goals that must be accomplished to commercialize FCVs. The first certainly involves safety in proving the durability and reliability of the fuel cell. Second, the cost of the fuel cell systems must be comparable to today's internal combustion engines. Third, depending on fuel choice, an alternate fuel infrastructure must be made available and convenient. Lastly, public acceptance must be secured in order to create demand for this technology. So the cycle for fuel cell vehicle commercialization incorporates safety from start to finish. In 1999, the Idaho National Engineering and Environmental Laboratory (INEEL) in Idaho Falls, ID, USA published "Safety Issues with H_2 as a Vehicle Fuel," by Lee Cadwallader and Stephen Herring for the US Department of Energy (DOE). A preliminary hazards list was compiled for pressure, chemical, temperature, materials, and toxicological issues for gaseous, liquid, slush, liquid organic hydride, and solid metallic hydride. The report concludes that H_2 leakage, combustion potential, and compressed and cryogenic gas containment issues are the primary FCV safety concerns. A review in the report of international operating experiences with both internal combustion and fuel cell engines using H_2 back to 1976 reveals examples of H_2-powered vehicles that survived rollovers and other crash scenarios with no H_2 leakage. So the report authors believe that "while there are still mishaps with H_2 in various industries, no safety issues are foreseen that would warrant cessation of H_2 use as a vehicle fuel". Now five years after the INEEL report, John Kolts, Manager of H_2 Programs at Argonne National Labs, comments that "Our overall safety concerns have effectively remained the same, although we know more and have better data from these additional years of hands on. H_2 experience in test FCVs to a much higher degree of safety and confidence." In his opinion, the use of H_2 as an energy carrier in FCVs deserves the same, but not inordinately more attention to safety as with other vehicle fuels and vehicle propulsion systems. "The potential safety issues for H_2 are different," he admits, "and these differences must be factored into design with absolute rigor, as required for any safe and reliable vehicle fuel system."

Automakers and FCV safety:

"We test all our FCV products relentlessly, as an integrated system," states Andreas Schell, Senior Manager, Advanced Vehicle Engineering for the Chrysler Group in Auburn Brinkerhoff, a global planning and management firm. The study examines risks with FCVs in a multistory public parking garage, a residential garage, and at a repair and maintenance facility. The purpose of the report, based on computational fluid dynamics (developed by Dr. Michael Swain) and applicable conventional building codes, is twofold. First, to provide general information to facility designers in developing facility plans, and second, to identify some of the important H_2 leak scenarios that might be encountered with FCVs. In compiling the report, government and industry experts were consulted, along with local fire officials. Limitations of different buildings relating to ventilation systems, geometry, and H_2 leak rate had to be taken into account for the study. This is also true for the onboard safety features of the vehicle equipment assumed. The results depend upon vehicle safety systems limiting the H_2 leak rate to 20 cubic feet per metre (CFM) when the fuel cell engine is on, and H_2 sensors that are capable of dependably detecting 1% levels of H_2 near a leak source. H_2 sensors identified for the vehicle could detect leaks in situations with low ventilation. None of the sources of ignition around the vehicles being modeled were included in the results. General industry practice and understanding holds that hydrogen cannot ignite unless it reaches a concentration level of at least 4.1% in air.

Opportunity in India:

Many of the pioneers of the fuel cell technology believe that highest efficiency along with cost reduction on fuel cells can be achieved if it is driven with pure hydrogen - that too generated from non- conventional energy sources e.g. biomass etc. fortunately in India sources of natural gas and renewable energies are in abundance. The estimated natural gas reserves in India, before recent large discoveries, were 685 billion cubic metre (24TCF). This enormous source of natural gas and proper and suitable diversification of biogas generation plant can be used to fuel the fuel cells.

Conclusion:

With the world energy demand expected to double by 2050 and our fossil fuel reserve getting void day by day - we are now facing a strong urge to find the way out - to find alternative measures to meet our growing demand at same time equally hygiene for our environment. The developed nations across the globe have already started shifting their dependence towards various renewable energy sources among them Fuel Cell Technology holds an enormous potency. There lie just a few barriers to make the fuel cell the best alternative among other renewable sources of energy. Rigorous research work in the field of fuel cell and the proper responsibility should have to be taken from different organization to solve the future energy problem.

References:

1. Several Issues of the Journals of SAE INDIA.
2. www.fuelcell.com <http://www.fuelcell.com>.
3. Several issues of *The Science Reporter*.