IOP Conf. Series: Materials Science and Engineering **376** (2018) 012103 doi:10.1088/1757-899X/376/1/012103

Fuel Cells-A Signpost to Future

Rumana Ali[1*], Anser Pasha[2]
[1]Assistant Professor, Department of Mechatronics Engineering, Mangalore Institute of Technology and Engineering, Moodabidri
[2]Assistant Professor, Department of Information Science & Engineering, Yenepoya Institute of Technology, Moodabidri

* Corresponding Author: rumana@mite.ac.in

Abstract: In a few decades, fuel cells have gained moreinterest as a zero emission source of energy. Fuel cells are intensive sources that extrude power from hydrogenand oxygen directly at low voltage. Fuel cells have passed demonstration stage, have been marketable because of the remarkable worldwide research and development. Fuel cells offer a promising alternative to conventional energy conversion technologies for a wide range of applications. Fuel cells can also be an interesting solution for many power sources. This paper presents an overview of different fuel cells and their applications emphasizing that fuel cells is a sign post to the future.

1. Introduction

The fast depletion of resources such as petroleum, coal, and natural gas forces leading to an increasing threat among the people to look for alternative regenerative energy sources, such as solar, wind, geothermal, and hydroelectric energies. The other course of action of saving expensive natural resources and solving the environmental problem is to develop cleaner and more efficient energy conversion devices. In recent years, fuel cell research and development have received much attention for their higher energy conversion efficiency and lower or non-greenhouse gas emissions than thermal engines in the processes of converting fuel into serviceable energies.

Fuel cells are the viable possible alternatives to batteries as portable energy sources that are being investigated at present. A fuel cell is an electrochemical device that produces electric power by means of a chemical reaction, similar to a battery. The general structure of a fuel cell is as shown in Figure.1.The main peculiarity between batteries and fuel cells is that the latter can produce electricity as long as fuel is supplied, while batteries extrude electricity from stored chemical energy and, hence, require frequent recharging. On the other hand fuel cells are more efficient than other conventional power sources because their efficiencies are not limited by Carnot cycle.

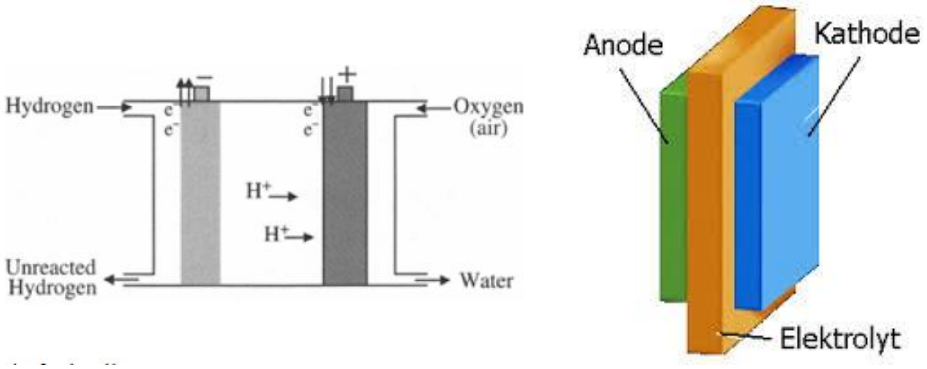

Figure.1 Fuel Cell

The major types of fuel cells are classified depending on the type of their electrolyte: alkaline fuel cells (AFCs), proton exchange membrane (PEM) or polymer exchange membrane fuel cells (PEMFCs), direct methanol fuel cells (DMFCs), phosphoric acid fuel cells (PAFCs), molten carbonate fuel cells (MCFCs) and Solid oxide fuel cells (SOFCs).The efficiency and operating temperature are discussed in section 2. The FC applications and developments are discussed in sections 3.

2. Fuel Cell Technology

Alkaline Fuel Cell (AFC): In AFC, an aqueous solution of KOH is used as the electrolyte. Alkaline fuel cells have been in actual use for a long time, delivering efficiencies of up to 60%. They require pure hydrogen as fuel and operate at low temperatures (at 80°C) less corrosive toward the electrodes. The limitations are sensitivity of the electrolyte to co2 requires the use of highly pure H2 as a fuel and if ambient air is used as the oxidant, the CO2 in the air must be removed.

Proton Exchange Membrane (PEM): PEM fuel cells use solid electrolytes with an efficiency of 40%and operate at low temperatures, allows rapid start-up. The advantage of PEM cells is that pure hydrogen can be used as a fuel.

Direct Methanol Fuel Cell (DMFC): A DMFC works on the same principle as the PEM, except that the temperature is increased to the range of 90 to 120°C and efficiency being 30% such that internal reformation of methanol into hydrogen is possible. This type of fuel cell is still in the design stages, because the search for a good electro catalyst to reform the methanol efficiently and to reduce oxygen in the presence of methanol is ongoing.

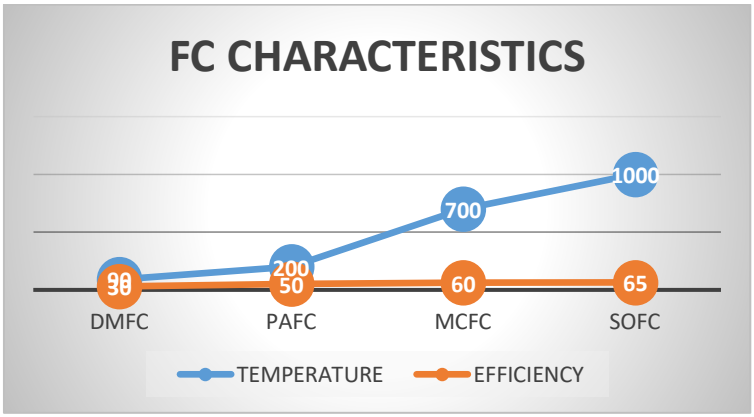

Figure.2 Fuel Cell Characteristics

Phosphoric Acid Fuel Cell (PAFC): The electrolyte used is phosphoric acid, and the cell operating temperature is about 200°C, efficiency being 40%.which makes some cogeneration possible .PAFC are the oldest type with an origin that extends back to the creation of the fuel cell concept.

Molten Carbonate Fuel Cell (MCFC): It operates at 600°C, efficiency being 50% and require CO or CO2 on the cathode side and hydrogen on the anode, originally developed to operate directly from coal.

Solid Oxide Fuel Cell (SOFC):SOFCs use a solid ionic conductor as the electrolyte yttria-stabilized zirconia as the electrolyte, required temperatures is 1000°C with efficiency of 60%**,** but the search for materials capable of serving as the electrolyte at lower temperatures resulted in the "intermediate temperature solid oxide fuel cell" (ITSOFC). A plot of the operating temperature and efficiencies versus different fuel cells is presented in Figure.2.

3. Applications of Fuel Cells

Fuel Cells applications can be broadly classified into three areas: Transportation – such as neighbourhood electric vehicles, golf cars, fork lift vehicles, Stationary – such as backup power for communication towers, data centres Portable – such as prime or auxiliary power for worksites, cottages, boats. There are applications which require a combination of fuel cell and other power source- hybrid application [1]. Fuel cells can be synthesized in the desired size for a precise application. Collectively this creates a total production volume that has driven cost down tremendously, making various applications commercially viable now. The DMFCs are preferable for several applications because of their low weight and volume. The DMFCs are developed swiftly to reinstate or support batteries, due to the high energy density of methanol. The DMFCs are assuring contender as portable power sources, since any fuel processing is not required and can operate at low temperatures. PEMFC is best suited for automotive power system as it has low operating temperature, high power density, and rapid start-up compared with the other fuel cells. PEMFC may also be used in residential and commercial power systems.NASA and the Russian space program have adapted AFCs over PEMs to stock up power, water & heat for all manned space vehicles, by the virtue to the AFCs greater fuel efficiency.The world's first fuel-cell boat HYDRA used an AFC system with 6.5 kW net output.Figure.3 shows fuel powered fork lift and boat.

Figure.3 Fuel Cell Powered Fork Lift and Boat

A. Fuel cells for Transportation

Fuel Cell hybrid electric scooter: The fuel cell hybrid electric scooter has an indigenous advantage, in comparison with the fuel-cell-vehicles like buses, since it uses a low-pressure metal-hydride hydrogen storage system. In this system the scooter has safety features, ease of accessibility, and

convenient hydrogen infrastructure. Also the low-pressure MHHS is the best hydrogen-storage technology for small vehicles such as scooters and other two wheeled vehicles. The progress of zero-emission fuel cell-based hybrid electric scooter would reduce environment pollution problems and improve energy independence. From the safety point of view, the low-pressure hydrogen storage, which is readily available, is an advantageous. The ultra-capacitors are utilized in addition to provide regenerative braking power, which yields faster response and also protects the battery. [3]

Fuel Cell Powered aero planes: Fuel cells generate auxiliary electric power for an airplane, thus reducing the quantity of fuel that must be carried on a trip better than propulsion engine power generators. As fuel cells are capable of converting fuel directly into electricity and heat,without the combustion in a hydrocarbon-fuel consuming engine,fuel cells are emission-free, thus cleaner for the environment. The prominent point here is it can also produce water, this water could be usedon-board a commercial airplane, reducing the amount that theplane needs to carry over a long-distance. [4]

Fuel Cell Powered Railways: In traction the drive systems have shifted from DC motors to AC motor based drives, thereby sharing the advantage of up gradation in power devices and their digital control. It has obvious advantages of reliability, efficiency, feasible, accuracy and control flexibility. The drive mainly comprises of a digital controller, power conditioner and motor. The Fuel Cell System uses a storage system named as Electrical Energy Storage System which has good potential in transportation applications. It can be an alternative to IC Engine based vehicle for suburban operation providing. It is non-polluting& can regenerate power during braking. Combining super capacitors and Li--ion batteries proves to be practical solution for electrical energy storage systems [5]

Fuel Cell Powered Unmanned Undersea Vehicles (UUV): A hybrid power system with a combination of fuel cells and batteries forms a structure of an Autonomous UnderwaterVehicle (AUV) or Unmanned Undersea Vehicles (UUV). AUVs andUUVs are vehicles that are used to operate underwater without human resident. It is helpful in oceanographic research data collection and auxiliary offshore tasks. UUVs are usually powered by lithium-ionsecondary batteries, which have low specific energy. The operation of these vehicles is improved by adapting fuel Cell EnergyPower Systems (FCEPS). An advanced technique includes a power generation system based on a PEM fuel cell which employs unadulterated hydrogen and oxygen produced by a replaceable chemical storage. [6]

B. Fuel cells for Stationary Applications

Fuel Cell Powered- UPS System: When there are power outages a fuel cell powered, line-interactive UPS systemrenders stablepower to the load. In future fuel cell have the potential to take over conventional UPS power sources such as engine generatorsbatteries. During the transient conditions such asinstantaneous power fluctuations, slow dynamics of the fuelpre-processor and overload conditions a super capacitor module can be added. An environmentally friendly, feasible and clean power back-up system is validated through simulations. [7].

Fuel Cell Powered -Smart Grids: In the present scenario fuel cell applications can also be used as an investment tool, and it can become a major player of energy for smart grids and smart cities. The main requirementfor its use is the notification of usage at least 10 minutes inadvance for hydrogen based systems and 2 hours in advancefor reformat gas based systems. With anelectrolyzer and hydrogen storage together the overall system canused as a controllable load to increase theutilization of renewable energies. [8]

Fuel Cell Powered-Surveillance Robots: For surveillance applications, mobile robots require high-withstanding power sources for long operation times. Batteries alone may not be able to aid, due to

their low energy density and same with the combustion engines due to noise. A high power Lithium ion battery, with a high energy density fuel cell forms a hybrid system is perfect for this application. One of the product in market is propane powered 200W solid oxide fuel cell developed by Ultra electronics. The fuel cell yields maximum efficiency when operated at full power or it needs to be turned off to conserve fuel [9]

Fuel Cell Powered-Telecommunication:

Telecommunication systems require long uninterrupted power supply, this can be enabled by fuel cell system. .Based on power and required uptime, a primary energy source as a hydrogen or a hydrogen containing fuel is used. The use of fuel cell in this type of application is a viable application where hydrogen fuelled Backup power systems are used. And also Power generators using widely available fuels such as methanol, ammonia or LPG have become available. This system should be fuelled using bottled hydrogen if a fuel cell system is deployed Backup system may operate during power outages and the conventional solution is batteries for lower output levels and diesel generators for larger power outputs, based on the power requirement. [10]

C.Fuel Cell for Portable Applications

Fuel Cell Powered-Portable Charger: Smartphone portable charger, from Swedish startup MyFC, hydrogen fuel cells are dominant over the lithium ion batteries. It is the world smallest and most powerful fuel cell charger in the world, and can be charged without ever having to touch a wall outlet. It has the water and ordinary salt (Na CI), it's delivered in a contained slim card. When the card is inserted into the charger – hydrogen is produced which in turn fuels up the fuel cell. [11]

Figure.4. MyFC Jaq Fuel cell powered smart phone charger

Fuel Cell Powered Portable Computer: It employs four-cell PEMFCs, a 6-phase boost converter, two cylindrical metal hydride storage tanks, a valve, air pump and a pressure sensor to adjust the hydrogen flow and a control unit to manage the whole system. The main attributes of the system are a flat, large area and self-humidifying stack consisting of four cells and a directly integrated, high-efficient converter for low input voltages. This structure is quite efficient for portable computers.

4. Conclusion

This paper has highlighted the applications of fuel cells in various fields. The vehicles, stationary & portable electronic devices powered by fuel cells are the most promising applications. Fuel cell powered systems can be configured taking into consideration the specific needs of an application and the local availability and costs of fuel. This flexibility, in combination with the high energy efficiency makes the fuel cell an interesting option for commercialization. The fuel cells are the boon to energy engineering and should be used as the main substitution for traditional power sources due to their unique and

relative advantages. Fuel cells can be marketable if stable and high-purity hydrogen is available. Also the existence of more efficient competitive power sources than the fuel cells is a hurdle. Another concern is the health and environmental benefits as well as the infrastructural aspects of traditional power supply and demand.

References

[1] Iqbal Hussain "Electric & Hybrid Vehicles: Design Fundamentals", CRC Press 2003
[2] J.-H. Wee "Applications of proton exchange membrane fuelCell systems ", *Renewable and Sustainable Energy Reviews 2007* pp.1720–1738
[3] Taehyung Kim, Oleg Vodyakho & Jefferson Yang "Fuel cell hybrid electric scooter " *IEEE Industry Applications Magazine* Mar -Apr 2011
[4] Henry Oman "Fuel-Cell Powered Airplane Propulsion "*lEEE & AESS Systems Magazine*. January 2004
[5] Naseam H Jafril M, Dr Susluna Guptal "An overview of Fuel Cells Application in Transportation" *IEEE Transportation Electrification Conference and Expo, Asia-Pacific (ITEC)* , pp. 129-133
[6] Gerardo Borgogna, Thomas Lamberti, Aristide Fausto Massardo "Innovative Power System for Autonomous Underwater Vehicle" *IEEE Conferences OCEANS - Genova*May 2015, pp.1-8.
[7] W. Choi, P. Enjeti and J.W. Howze "Fuel Cell Powered- UPS Systems" *Power Electronics Specialist Conference, 2003. PESC '03. 2003 IEEE 34th Annual* 2003, pp. 385 – 390.
[8] Paul A. Bernstein Maik Heuer "Fuel Cell System as a Part of the Smart Grid", *2013 IEEE Grenoble Conference* pp.1-8.
[9] JasonB.Siegel; Y.Wang; Anna.G.Stefanopoulou; Buz.A.McCain"Comparison of SOFC and PEM Fuel Cell Hybrid Power Management Strategies for Mobile Robots" *IEEE Vehicle Power & Propulsion Conference*, pp 1-6.
[10] Frank de Bruijn and Pieter Veltman "PEM Fuel Cells for Telecom Applications From Backup to Continuous Power*" IEEE 33rd International Telecommunications Energy Conference*,pp 1-6.
[11] https://myfcpower.com/-Smart Phone charger.