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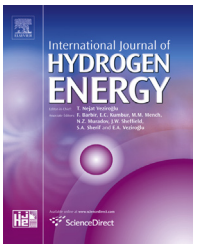

Advances in stationary and portable fuel cell applications

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ABSTRACT

The reliance on fossil fuels is one of the most challenging problems that need to be dealt with vigorously in recent times. This is because using them is not sustainable and leads to serious environmental issues, such as: air pollution and global warming. This condition affects economic security and development. An alternative to fossil fuel is highly possible which will be more environmentally friendly, sustainable and efficient as well. Among all the different technologies associated with renewable energy, fuel cell technologies represent one of the most promising technological advancement to curb the situation.

In this paper, an overview of the technology and its advantages and disadvantages compared with competitive technologies was revealed. The application of different fuel cell types in the stationary and portable sectors was covered. Furthermore, recent challenges and promising developments of current fuel cell technologies in different studied applications were reviewed. Some possible solutions to the challenges were named in this paper for both the portable and stationary fuel cell applications. The paper further seeks to expose the world to the current progress made in the fuel cell industry up to date and possible areas that needs intensified research and modifications to make the fuel cell industry more vibrant and buoyant.

Introduction

One of the biggest challenges the world is facing is to find suitable, sustainable and clean replacements for fossil fuels. Fossil fuels are ultimately unsustainable, and depending on them as main power source leads to serious environmental issues such as pollution and climate change, along with economic and political issues related to the economy, security, and the political problems affecting the exporting countries. On the other hand, the use of renewable energy is already growing. Of the 300 GW of new electricity generation capacity built globally between 2008 and 2009, about 140 GW was the capacity generated from renewable sources. In 2005, renewables produced 16.5% of world primary energy. According to the special report on renewable energy sources and climate change mitigation (SRREN) [1,2], renewable energy could account for almost 80% of the world's energy supply within four

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decades. Fuel cells technology is one of the most promising technologies that can be developed in relation with the increasing renewable energy supply.

Fuel cell according to [3,4] is gradually becoming a practical technology option that competes with conventional internal combustion engine generators and batteries. In 2012, shipment of fuel cell systems increased appreciably almost double that of the previous year to reach a total of 45,700 units. This figure in 2013 was also anticipated to increase by a margin of 46% approaching about 67,000 units. Stationary fuel cells experienced the largest growth compared to the three main sectors. The standout performer for fuel cell technology is currently the stationary sector. Its application is normally found in different sizes; from small – scaled grid connected micro combined power heat and power units for residential use, to off – grid backup power systems providing uninterrupted power supplies to critical infrastructure, and prime power for buildings and even to megawatt – scale installations designed as grid – connected power stations.

Based on events in 2014, it is again anticipated that 2015 will be one of the years of massive progress and development in the fuel cell industry. This will surely be highly experienced in the three [5,6] main regions for hydrogen fuel cells (HFC) markets, that is, Europe, Asia and North America. In 2014, California remained number one in the United States in the commercialization of HFC. This transformation was also seen in Japan with 41 hydrogen fueling stations (HFS) being implemented due to the enforcement of positive measure and massive support for HFC. Korea within the same year built the Gyeonggi Green Energy, 59 MW as well. This is currently the world's largest fuel cell park for the stationary market. By July 2014, Korea announced the commencement of the Pyeongtaek, 360 MW which is anticipated to be completed by 2018.

The fuel cells annual report 2014 also stipulated how the portable sector was going through some difficulties to support the financial and commercial viability of the HFC market but the release of the Upp^{Tm}, a USB compatible charging device by the Intelligent Energy (IE) changed the general perception and future of the portable sector. The transport industry also saw massive progress as more fuel cell electric vehicles (FCEV) were manufactured. Hyundai for instance introduced the I × 35 FCEV, while Toyota during that period also generated the Mirai 2015.

Fuel cell overview

A fuel cell is an electro-chemical power source which converts chemical energy in the form of fuel directly into electrical energy [7]. Fuel cells technology allows the direct conversion of chemical energy to electrical energy, instead of the multi-step processes involved in combustion-based heat engines [8,9]. However, unlike other electro-chemical power sources such as batteries which store their reactants within a cell, the reactants are fed continuously to the fuel cell from external stores. Also, the electrodes in a fuel cell are not consumed as in a battery, irreversibly in a primary cell and reversibly in a secondary cell, and do not take part in the reaction. Fuel cells are identified as one of the most promising technologies that are significantly related to the renewable energy development [7,10].

Although the concept of a fuel cell was developed in England in the 1800s by Sir William Grove, the first workable fuels cells were not produced until much later, in the 1950s. During this time, interest in fuel cells increased, as NASA began searching for ways to generate power for space flights [11]. Fuel cells technology is nowadays considered as one of the most promising technologies that are needed to develop in according with the increasing renewable energy supply. Employing fuel cells eliminates pollution caused by burning fossil fuels, as the only by-product is water, and they don't need conventional fuels such as oil or gas and can therefore eliminate economic dependence on politically unstable countries. Alternatively, hydrogen and other fuel cell fuels can be produced anywhere and on different scalable volume, which leads to more stabilized and decentralized power grid on the long term. Fuel cell systems perform with the highest efficiency compared to conventional distributed energy systems, and they are able to produce near-zero greenhouse emissions if working with renewable clean resources [11–15].

Compared with combustion engines, fuel cells have no moving parts (except for pumps or compressors in some fuel cell plant subsystems), which allows silent, vibration-free and noise-less operations, with less maintenance required. Fuel cell operating temperatures vary from around 80 °C for low-temperature PEMFCs to around 1000 °C for MCFCs. Temperatures inside combustion engines may reach over 2000 °C. Compared with batteries, fuel cells nearly provide instantaneous recharge capability [7,16]. They can use a variety of different fuels to generate power (e.g. hydrogen, methanol, fossil fuels to biomass-derived materials, etc.). Fuel cells in general can offer longer operating times, operating on much wider range of temperature, and having less environmental issues associated with disposal. Advantages of fuel cells over each of combustion engines and batteries are summarized in Table 1.

Fuel cells are already commercially used to generate electricity for some applications, including in spacecraft and in few stationary uses, such as emergency power generators. Today, fuel cells have reached a level of development from which it is possible to indicate that they have promising markets in which electricity must be produced with high efficiency and low environmental impact [12]. Moreover, numerous fuel cell-based power plants have been built and operated successfully, on different scalable designs from tens of megawatt to a few milliwatts [13]. However, fuel cell cost is one barrier that is facing the commercialization of fuel cell technology in different applications. Fueling fuel cells is another fundamental problem since the production, transportation, distribution and storage of reactant is still technically challenging. Other limitations include the durability and reliability of the fuel cell system. In this paper, an overview of the fuel cell technology and its different types is given. Application of different types of fuel cells is covered in the stationary and portable power sectors. Furthermore, this paper highlighted the main challenges associated with using different fuel cell types in the studied applications. Recent developments that deal with the proposed challenges were reported.

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