**Asian Journal of Research in Social Sciences and Humanities**
ISSN: 2249-7315 Vol. 11, Issue 11, November 2021 SJIF 2021 = 8.037
A peer reviewed journal

# FUEL CELL TECHNOLOGIES AND POWER ELECTRONIC INTERFACE: A REVIEW

**Diptonil Banerjee***

*Faculty of Engineering,
Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, INDIA
Email id: nilju82@gmail.com

**DOI: 10.5958/2249-7315.2021.00271.9**

## ABSTRACT

*Because of growing power consumption, the volatility of rising oil costs, and environmental concerns, renewable energy is becoming more important. Fuel cells are becoming increasingly popular amongst renewable energy owing to their greater efficiency, cleanliness, and cost-effective power supply desired by customers. This article provides a thorough examination of several fuel cell technologies, including their operating principles, benefits, drawbacks, and appropriateness for residential/grid-connected systems, transportation, industry, and commercial applications. It is explained how to create a mathematical model of a fuel cell that will be used in a simulation research. The need for a suitable power-conditioning device to connect the fuel cell system with self-contained applications is also discussed in this article.*

**KEYWORDS:** *Converter, Distributed Generation, Power-Conditioning Units, Renewable Energy, Sources Fuel Cell Systems.*

## 1. INTRODUCTION

Because of increased consumer awareness about protection of the environment and the finite nature of fossil fuels, most of the research effort has shifted to alternative/ renewable energy sources. Small-scale generating systems such as wind turbines, photovoltaic, micro-turbines, fuel cells, and other small-scale generation systems play an essential part in meeting consumer demand utilizing distributed generation ideas[1][2]. The phrase "distributed generation" refers to any small-scale generating that is placed close to consumers rather than in a central or distant location. According to a survey, India's total transmission, distribution, and transformer losses were about 32.15 percent by the end of 2005. The main advantages of distributed generation systems (DGs) are lower transmission and distribution line losses, lower installation costs, local voltage control, and the flexibility to add a small unit rather than a bigger one during peak load circumstances. Fuel cells are attracting increasing attention among the many distributed generating options since they have the potential to provide both heat and electricity. Fuel cells are stationary energy conversion devices that directly transform the chemical process of fuels into electrical energy while also producing water as a byproduct[3][4].

Traditional heat engines, on the other hand, generate electricity from chemical energy via intermediary mechanical energy conversion, resulting in lower efficiency than fuel cells. Fuel cells combines the greatest qualities of engines and battery packs: they can run for as long as there is fuel available without any intermediary mechanical energy conversion, and their properties under load are comparable to those of a battery. Some of the unique problems in distributed power production, such as how to connect fuel cells to the grid and how to regulate grid voltage and frequency to enhance supply quality, are also addressed. Given the vast potential of fuel cell-based distributed generation, a thorough examination of the fundamentals of fuel cell technology, I–V characteristics, and power-conditioning units is necessary[5]. This article compares and contrasts several generating systems based on their percentage efficiency, capital, and maintenance costs. A comparison of various fuel cell types is also provided based on the available research[6][5]. A discussion of the fundamental principles of operation, classifications, benefits, drawbacks, and applicability of applications is given. An essential issue is the need for an appropriate energy unit. When compared to traditional systems and alternative distributed generating systems, the efficiency of fuel cells is always greater. When compared to other distributed generation technologies, the fuel cell offers additional benefits such as high energy conversion efficiency, zero emissions, flexibility, scalability, rapid installation, and excellent cogeneration possibilities[7].

## 2. DISCUSSION

### 1. *Fuel cells technology:*

Swiss physicist Christian Friedrich Schoenbein developed the fundamental concept of the fuel cell in 1838. Sir William Grove invented the first fuel cell in 1839 when he accidentally reversed the electrolytic of water. Francis Bacon exhibited the first 5 kW alkali fuel cell Cambridge University in 1950. NASA required a small device to produce energy for space shuttle uses after the effective achievement of alkaline fuel cells[8]. Global fuel cells developed a 12 kW alkaline fuel cell for Space transportation orbiter in the 1970s to provide dependable power without the use of battery or backup power. Since the mid-1960s, researchers have been working on improving different fuel cells for uses such as stationary electricity and mobility. Furthermore, government organizations in the United States, Canada, and Japan have boosted their support for fuel cell research and development. However, due of its main disadvantage of greater installation costs, it was taken into consideration in many nations after 50 years. Following the invention of power conversion devices, more study is being focused on fuel cells in order to lower their higher infrastructure costs[9][10].

### 2. *Working principle:*

A fuel cell is a power conversion device that transforms the hydrogen gas of a process into electricity with the addition of water and heat as a byproduct. Figure 1[11] shows the structure of a simple fuel cell. An aqueous layer is in touch with two electrodes on each side of the fuel cell. The anode electrode receives a constant supply of hydrogen fuel, while the cathode electrode receives a constant supply of oxidant (or oxygen from the air). The hydrogen is produced at the Anode Terminal[12].

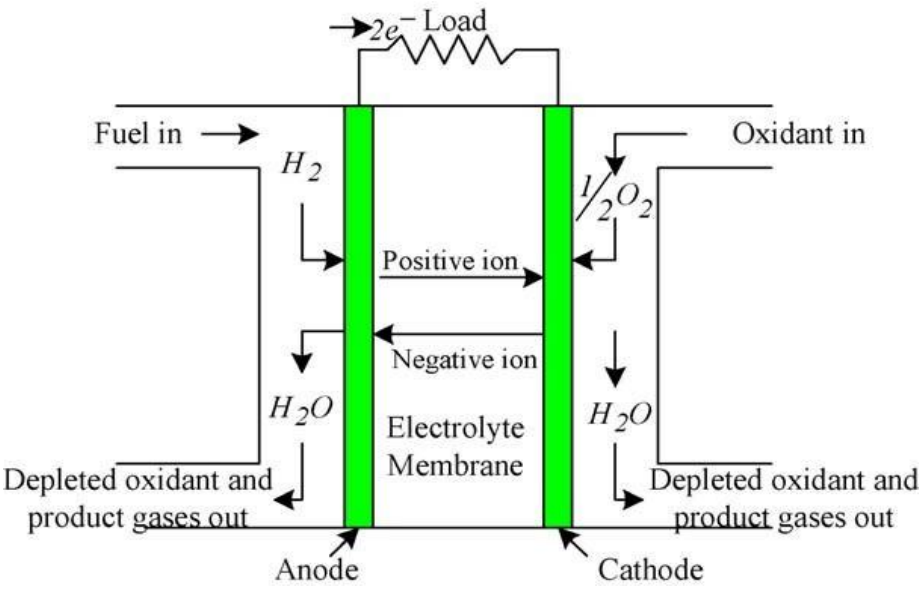

**Figure 1:** The Structure of a Simple Fuel Cell.

The intermediary electrolytic membrane serves as an insulator for electrons, allowing only positive ions to pass from anode to cathode. For the system to become stable, these electrons need to combine on the opposite side of a membrane, which is why the free electrons were transferred to the cathode side through an external electrical connection. At the cathode, the positive and negative ions recombine with the oxidant to produce depleted oxidant (or) pure water[13]. The chemical processes that occur in the anode and cathode, as well as their cumulative effects, are listed below.

Anode reaction: $H_2 = 2H^+ + 2e^-$

Cathode reaction: $1/2O_2 + 2H + 2e^- = H_2O$

Overall reaction: $H_2 + 1/2O_2 = H_2O$

## 2. *Classification of Fuel cells:*

The fuel cells are categorized based on the electrolytes and fuel used. There are now six main kinds of fuel cells available. I Proton exchange membrane fuel cell (PEMFC): A proton exchange membrane fuel cell (PEMFC) is a kind of fuel cell that uses a Direct formic acid fuel cell (DFAFC) and Direct Ethanol Fuel Cell (DEFC) are two types of fuel cells (DEFC). ii) Alkaline fuel cell (AFC): proton ceramic fuel cell (PCFC); direct borohydride fuel cell (DBFC) (DBFC). Phosphoric acid fuel cell (iii) (PAFC) molten carbonate fuel cell (iv) (MCFC) (vi) Direct methanol fuel cell (v) Solid oxide fuel cell (SOFC) (DMFC) They're further divided into groups based on their operational temperatures. PEMFC, AFC, and PAFC have low working temperatures in the range of (50–250) 8C, whereas MCFC and SOFC have higher working temperatures in the range of (650–1000) 8C. The major benefits, drawbacks, and appropriateness of application of all fuel cells are briefly discussed based on a review performed[14][15].

## 3. *Recent development in fuel cells:*

The optimum size of a fuel cell is critical for locating the fuel cell in a dispersed system to satisfy peak load needs for various utility applications. This classic article lists the many intermediate ranges of different fuel cells currently on the market, ranging from 0.5 kW to 2 MW. The study focuses on PEM, MCFC, and SOFC fuel cells in particular, with the goal of lowering the cost of the fuel stacks and increasing their life lifetime to over 40,000 hours. Currently, plug power is developing a PEMFC with a capacity of 7 kW for residential applications, while the Ballard power generating system is testing a PEMFC with a capacity of 250 kW. The DOE and Fuel Cell Energy, Inc. have conducted extensive research on MCFCs for stationary power applications. The biggest distributed energy power plant is a 1.2 MW system in Santa Clara, CA, and the development of 250, 300, and 400 kW capacities MCFC for cogeneration is being studied in different nations such as Europe, Holland, Italy, Germany, and Spain. In the same way, the SOFC has been successful in stationary power applications. Siemens Westinghouse has built and tested a 250 kW hybrid system with fifty two percent of accuracy, and work is now underway to create SOFCs in various ratings like as 1 and 25 kW. They're also working on a 5 kW SOFC-GT system with a high efficiency to minimize the system's expensive installation costs. Furthermore, PEMFC and PAFC systems for heating and power production are being studied further. For commercial applications, the study is concentrating on the development of 100 kW to 1 MW DMFCs, as well as additional fuel cell types such as DFAFC, DEFC, PCFC, and DBFC[16][17][18].

## 4. *I–V characteristics of fuel cells:*

Typically, the fuel cell voltage is about 1.2 V. Because of its low output voltage, several cells must be stacked in series and parallel to enhance their power capacity. Typical fuel cell show polarization characteristic as a function of electrical voltage and current density. Because of the ohmic nature of a current, the voltage decreases as the current density rises, indicating the existence of a linear area. This is known as ohmic polarization, and it occurs mostly as a result of domestic resistance provided by different components. The ohmic loss is less important at low current levels, and the rise in output voltage is mostly due to chemical reaction activity (time taken for warm up period). As a result, active polarization is another name for this area. The voltage drops considerably at extremely high current densities owing to a decrease in gas exchange efficiency, which is mostly due to over-flooding of the catalyst; this area is also known as interfacial tension. Thermodynamics and electrical efficiency of the system help to enhance the fuel cell's performance. The system's thermodynamics efficiency is determined by how it processes fuel, manages water, and regulates temperature. However, numerous losses such as ohmic loss, activation loss, and concentration loss affect the electrical efficiency of fuel cells. Fuel cells vary in terms of features, building materials, and application appropriateness. Military, space, portable devices, residential, fixed, and transit uses all fall under this category[19][20].

### 5. *Comparison of different fuel cells:*

Due to its low working temperature (50–100 8C) and quick start-up, PEM fuel cells are better suited for residential and commercial applications, but MCFC and SOFC are the best options for medium and large power applications. SOFCs operate at the maximum temperature of any fuel cell, resulting in extremely high efficiency, internal reforming, fuel flexibility, and elevated side product heat for co - generation. With integrated cogeneration activities and minimal greenhouse gas emissions, the system's efficiency may reach as high as 80%. However, the high initial cost is the most significant disadvantage. As a result, more research is being done on these fuel cells in order to lower the working temperature and lower the installation cost. These features have made SOFC an appealing emerging technology for stationary power generation with capacities ranging from 2 kW to several MW. The AFC is utilized for a variety of specific space projects, whereas the PAFC is used for transportation and business reasons. More than 2500 fuel cells have been deployed in stationary applications such as hospitals, hotels, schools, communications offices, and utility power plants throughout the globe. The laptop can run for 20 hours and the phone for 30 days without recharging, demonstrating that the fuel cell can provide more power than batteries[21][22].

### 6. *Units for power conditioning (PCUs):*

Given the falling characteristics of fuel cells, the development of power-conditioning units (PCUs) is critical for connecting fuel cells to stand - alone systems. Due to its greater manufacturing cost, the only fuel cell accessible on the market is in the 25–50 V range. Single step dc/ac inverter topologies or a combination of a dc/dc conversion in series with a dc/ac inverter creating multistage conversion are used to convert the produced fuel cell voltage into directly ac supply. The choice of a power system is dependent on a number of important criteria, including cost, efficiency, electrical isolation, ripple-free operation, and reliability. The conduction and switching losses determine the power-conditioning unit's efficiency. By decreasing the number of components used and their working ranges, conduction losses may be efficiently minimized. Soft switching methods, such as zero voltage crossing (ZVS) and zero current crossing (ZCS), may decrease switching losses. Soft switching techniques provide a number of benefits over hard switching circumstances, including a 20–30% reduction in device losses. The choosing of topology must have a low number of partial products in order to minimize costs and improve dependability. Furthermore, an electrical separation is needed to safeguard the fuel cell stacks in the event of an overload[23][24][25].

## 3. CONCLUSION

This article provides an in-depth examination of fuel cell technologies for home and matrix distributed generating systems (DGs). The working principles and chemical processes involved in various fuel cells, as well as their polarizing curve, are addressed in terms of fuel inputs, electrolyte, benefits, disadvantages, and application appropriateness. Recent advances in fuel cell technology are thoroughly examined, and comparisons of several fuel cells are done. The PEM offers a high power density, fast start-up, and cheapcost, extended life span, and is virtually appropriate for all applications, as the review shows. However, because of their greater efficiency, inner reforming, and hybrid systems' heating and power cogeneration, the MCFC and SOFC are the best choices for medium and large power applications. The variety of various power electronic interface devices for dc/dc converters and dc/ac converters is examined and compared in this article. Some of the major problems that need more focused study are cost reduction, increased life duration of over 40,000 hours, and development of power-conditioning systems for independent as well as grid interface.

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