Information Sheet #100

The ultimate solution for maintaining your nationwide generator network

ULTIMATE SERVICE ASSOCIATES
A NORTH AMERICAN SITE SERVICES CO.

Fuel Cell Types & Applications Within Power Generation

1.0 Introduction:

For several years, fuel cells have had a small share of the standby generator and Combined Heat and Power (CHP) market. There are various types of fuel cells available for industrial/commercial applications, with some more suitable to CHP than standby. One such application is connecting fuel cells to the electric grid to provide supplemental power. To date, costs and fuel availability have limited fuel cell application to niche markets, with engine-driven generator systems dominating the standby generator market. However, fuel cells near zero emissions, high efficiency, very high reliability with no moving parts, and advances in catalytic technology, are leading the industry to plan for a greater share of the market.

This information sheet discusses the various types of fuel cells, which applications are better suited for different types of fuel cells, and issues to be overcome before fuel cells take a greater share of the power generation market.

Primary Types of Fuel Cells and Typical Application

Figure 1. Types of Fuel Cells in Use Today (*While there are more varieties these are in use the most*)

Fuel Cell Type	Fuel	Electrolyte	Average kW Range	Application
Proton Exchange Membrane	Hydrogen	Proton-conducting polymer membrane	10 - 200 kW	UPS to critical loads, i.e. data centers
Alkaline	Hydrogen	Potassium hydroxide	1 - 100kW	Aerospace, power, heating & pure water
Phosphoric Acid	Hydrogen	Phosphoric acid	100 - 400 kW	Stationary & mobile applications
Molten Carbonate	Natural and Bio Gas	Molten carbonate salt mixture	0.3 to 3MW	CHP to larger facilities, standby and prime power
Direct Methanol	Methanol	Proton-conducting polymer membrane	1 - 400kW	Portable & emergency power applications

Data Center Application with PEM Hydrogen Fueled Fuel Cell Providing UPS Power to Data Center Critical Loads

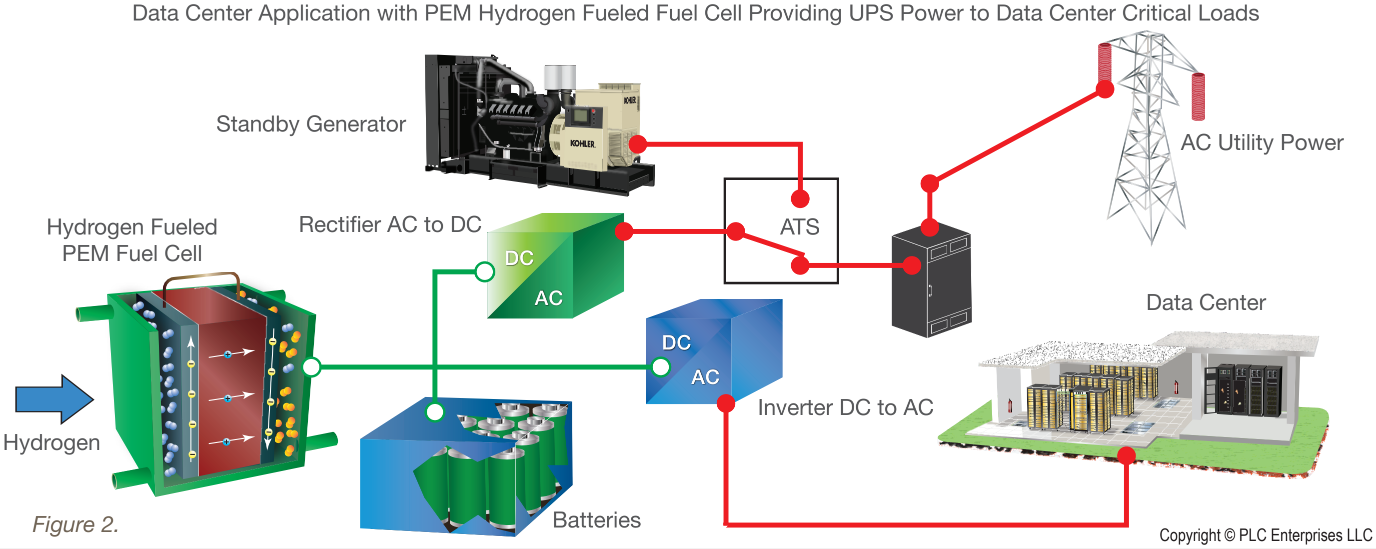

Figure 2.

To fulfill our commitment to be the leading network service provider in the Power Generation Industry, the USA, Inc. team maintains up-to-date technology and information standards on Power Industry changes, regulations and trends. As a service, our **Information Sheets** are circulated on a regular basis, to existing and potential Power Customers to maintain awareness of changes and developments in engineering standards, electrical codes, and technology impacting the Power Generation Industry.

2.0 Types of Fuel Cells:

Fuel cells generate electricity through an electrochemical reaction with no combustion and moving parts, as opposed to an engine-driven generator system (Reference info-sheet on Hydrogen Fuel Cells). There are several varieties of fuel cells; see figure 1; they all operate on the same principal, with the main differences between the types being fuel input, operating temperature range, material used, and size.

While there are other types of fuel cells, predominately existing applications use the following five versions:

- Proton Exchange Membrane Fuel Cell
- Alkaline Fuel Cell
- Phosphoric Acid Fuel Cell
- Molten Carbonate Fuel Cell
- Direct Methanol Fuel Cell

3.0 Proton Exchange Membrane Fuel Cells (PEMFC):

The public's perception of the fuel cell is the PEMFC. It is light weight, starts fast, operates at relatively low temperatures, can be built into a compact envelope, and when fueled by hydrogen emits water. With zero emissions, it is seen as a replacement for car and truck engines and an alternative to battery-operated vehicles. However, it can also be used for prime and standby generator applications, both stationary and mobile. Storage of fuel is easier in stationary generator applications.

While having a relatively low cost compared to other fuel cells, the use of a platinum catalyst between the electrolyte and the anode and cathode, makes it more expensive than battery vehicles. It can run on several fuels including hydrogen, methanol, and formic acid.

3.1 Generator Applications for PEMFC:

Portable and stationary power applications where zero emissions are preferred use hydrogen-fueled PEMFCs. For residential power (3 to 7kW) and commercial buildings (50 to 500kW), with some use in portable packages of 500kW. Because fuel cells generate DC current that has to be converted to AC current via an inverter with a battery in the circuit, they can also provide an uninterrupted power supply (UPS) to hospitals and data centers, two critical power applications with zero tolerance for power interruptions. The UPS option and ability to store hydrogen makes PEMFCs more viable. ***See Figure 2***

4.0 Alkaline Fuel Cells (AFC):

The advantages of AFCs are they operate at 80ºC, the electrolyte is potassium hydroxide KOH, powered by hydrogen, electrodes don't have to be expensive metals (making them the cheapest fuels to manufacture), high electrical generation efficiency up to 70% (higher than PEMFC), and a good power density. While having many advantages over PEMFC, AFCs using pure Oxygen (O_2) but air are subject to CO_2 in the atmosphere polluting the reaction. Some future developments may solve this issue.

4.1 Generator Applications for AFC:

The very efficient fuel cell is primarily used in the aerospace industry to provide power, heat and drinking water. NASA uses pure oxygen so the issue of CO_2 polluting the reaction is not an issue found on other earth bound applications.

5.0 Phosphoric Acid Fuel Cells (PAFC):

These were the first fuel cells to be commercialized. The PAFC uses liquid phosphoric acid as an electrolyte saturated in a silicon compound. The electrodes are made of carbon paper coated with a finely dispersed platinum catalyst. Operating at 150 to 200ºC, the water generated can be converted to steam in Combined Heat and Power (CHP) applications. Efficiencies of up to 42% are possible (higher thermal efficiency if used with CHP) and they are CO_2 tolerant, unlike AFCs. Their low power density and hazards due to the chemicals used in the electrolyte have limited their use to stationary power applications.

5.1 Generator Applications for PAFCs:

Are applied to stationary power applications to generate output from 100 to 400kW. With the higher operating temperature, the expelled water is ideal for CHP applications. Primarily used in stationary generator systems in the range 100 to 400kW.

6.0 Molten Carbonate Fuel Cells (MCFC):

MCFCs are high temperature fuel cells, operating at 600ºC or more. They have a much higher efficiency of approximately 60% and when used in a CHP application total efficiency can be as much as 85%. The electrolyte used is a molten carbonate salt mixture suspended in a porous ceramic matrix of beta-alumine solid electrolyte. Operating at such high temperatures permits the use of non-precious for the catalysts between the nickle (Ni) based anode and lithium (li) based cathode. With MCFCs operating temperatures, the fuels used, natural gas, bio gas and coal, can be converted to hydrogen within the fuel cell itself by a process called internal reforming. Disadvantages of MCFS are mainly the high operating temperatures and corrosive electrolytes that lead to component breakdown and lower cell life.

6.1 Generator Applications for MCFCs:

Are applied to larger stationary power applications with outputs from 300kW to 3MW. They operate at high temperatures which limits their applications. The high efficiency when applied to CHP applications can result in 90% thermal efficiency. They are more suited to load applications needing continuous base power including prime power stationary generation, cogeneration/CHP and marine transportation. While emitting less CO_2 than fossil fuel plans they are not carbon free.

7.0 Direct Methanol Fuel Cells (DMFC):

DMFCs are a methanol fueled sub-category of PEMFCs. The principal advantage over PEMFCs is their use of methanol, a fuel a lot easier to transport and store than hydrogen but still with a reasonable fuel density and stability through many environments.

7.1 Generator Applications for DMFCs:

DMFCs are an alternative power generator to PEMFCs because they use the hydrogen in methanol and not pure hydrogen that has a much lower power density requiring it to be compressed and super cooled. The military use them for quiet prime power and the low thermal signature. Other applications include man-portable tactical generators for military, disaster recovery power packs, and small to larger battery chargers.

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