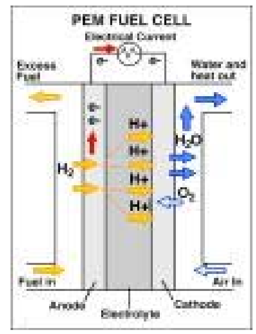
United States
Environmental Protection
Agency

Auxiliary and Supplemental Power Fact Sheet: Fuel Cells

DESCRIPTION

This fact sheet describes the use of Fuel Cells as Auxiliary and Supplemental Power Sources (ASPSs) for wastewater treatment plants (WWTPs). A fuel cell is an electrochemical device similar to a battery. While both batteries and fuel cells generate power through an internal chemical reaction, a fuel cell differs from a battery in that it uses an external supply that continuously replenishes the reactants in the fuel cell. A battery, on the other hand, has a fixed internal supply of reactants. The fuel cell can supply power continuously as long as the reactants are replenished, while the battery can only generate limited power before it must be recharged or replaced. Fuel cells have been a popular choice as an ASPS in recent years, because they are highly efficient and emissions-free. Although there are many different types of fuel cells, each of which uses its own specific set of chemicals to produce power, only molten carbonate fuel cells (MCFC), phosphoric acid fuel cells (PAFC) and solid-oxide fuel cells (SOFC) can generate enough energy to power a typical WWTP. Each of these types of fuel cell is appropriate for use as either a supplemental power source or an auxiliary power source.

A fuel cell contains hydrogen on its anode (negatively charged electrode) side and oxygen on its cathode (positively charged electrode) side. In contrast, conventional batteries consume solid reactants, such as Lead (Pb), Cadmium(Cd) or other metal. Once these reactants are depleted, they are discarded or recharged. Batteries can be regenerated either with electricity or by replacing the electrodes. In a fuel cell, reactants flow in and reaction products flow out. This makes continuous long-term operation feasible as long as these flows are maintained.



Fuel Cell Schematic

An electrolyte separates the anode and cathode sides. The electrolyte varies depending on the type of fuel cell being used. On the anode side, hydrogen diffuses to the anode catalyst where it dissociates into protons and electrons. The protons are conducted through the membrane to the cathode catalyst, but the electrons are forced to travel in an external circuit because the membrane is electronically insulating. This external circuit is the power supplied by the fuel cell. On the cathode side, oxygen molecules react with the electrons, which have traveled through the external circuit, and with hydrogen ions to form water.

Molten carbonate fuel cells (MCFCs) use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide ($LiAlO_2$) matrix. These cells have fuel-to-electricity efficiencies of between 60 and 85 percent, meaning 60 to 85 percent of the energy generated by the chemical reaction can be harnessed as useable power. MCFCs operate at about 1200° F (650° degrees C). This high temperature is needed to achieve sufficient conductivity of the electrolyte. Since they operate at extremely high temperatures non-precious metals can be used as catalysts at the anode and cathode, reducing costs. MCFCs are available in the range of 10 kW to 2 MW.

Phosphoric acid fuel cells (PAFCs) use liquid phosphoric acid as an electrolyte; the acid is contained in a Teflon-bonded silicon carbide matrix, and porous carbon electrodes containing a platinum catalyst. Operating temperatures range from 300° to 400° F (150-200° C). PAFCs generate electricity at more than 40 percent efficiency. In addition, 85 percent of the steam by-product from the chemical reaction can be used for cogeneration activities, such as heating onsite buildings and keeping WWTPs operating at optimal temperatures, thus reducing the use of commercial electric power. Existing PAFCs have outputs up to 200 kW.

Solid oxide fuel cells (SOFCs) are primarily used in big, high-power applications, including industrial and large-scale central electricity generating stations. A SOFC system usually uses a hard ceramic material of solid zirconium oxide and a small amount of ytrria (the oxide of the element yttrium) instead of a liquid electrolyte. Operating temperatures are around 1800 degrees F (1000° C). This high temperature operation removes the need for precious-metal catalyst, thereby reducing cost. Power generating efficiencies are around 60 percent. In addition, 85 percent of the steam by-product from the chemical reaction can be used for cogeneration activities thus reducing the use of commercial electric power. Existing SOFCs cells have output around 100 kW.

ADVANTAGES & DISADVANTAGES

A common misconception of fuel cells is that hydrogen is the source of energy. Hydrogen is not the primary source of energy; it is only an energy carrier and must be manufactured using energy from other sources. Some critics argue that the energy needed to create the fuel in the first place may reduce the ultimate energy efficiency of the system to below that of the most efficient gasoline internal combustion engines. This is especially true if the hydrogen has to be compressed to high pressures or liquified. Most types of fuel cells can operate on a wide variety of fuels including hydrogen, carbon monoxide, natural gas, propane, landfill gas, diesel, and simulated coal gasification products. In some cases, such as at a WWTP, methane (natural gas) from anaerobic digesters can be reused in the fuel cell instead of flaring off the excess. Other advantages of fuel cells include few moving parts, modular design and negligible emission of pollutants.

The high operating temperature serves as a big advantage for the MCFC. This leads to higher efficiency, since breaking of carbon bonds occurs much faster at higher temperatures. Other advantages include flexibility to use more types of fuels and the ability to use inexpensive catalysts. A major disadvantage of MCFCs is that high temperatures enhance corrosion and the breakdown of cell components.

One of the main advantages of PAFCs is they can use impure hydrogen as a fuel, removing the need of pretreatment of the fuel supply. Also the PAFC technology is the most mature. Utilization of steam by-products for cogeneration can improve the overall economic value of the technology. Disadvantages of PAFCs include the need for expensive platinum as a catalyst, relatively low current and power generation compared to other types of fuel cells, and their generally larger and heavier size.

Advantages of SOFCs are similar to those of the MCFCs, including higher operating temperatures. These high operating temperatures imply higher efficiency and flexibility to use more types of fuels. The higher temperatures also allow SOFCs to use inexpensive catalysts. Utilization of steam by-products for cogeneration can improve the overall economic value of the technology. One disadvantage of these high temperatures is that they enhance corrosion and the breakdown of cell components.

COST

Fuel cell manufacturers currently publish a commercial entry price of about $2,400/kW. Initial price does not include installation, balance of systems costs, or other miscellaneous costs that can drive the entry price up by 30% to 50%. Manufacturers believe that the entry price where fuel cells could compete successfully with other small power generators would have to be roughly half of the current price. This would allow for more competition for smaller scale installations. Through improved manufacturing techniques, higher efficiency and increases in production the cost of manufacturing reliable fuel cells is decreasing. As this technology becomes more commercial available, costs of fuel cells will rapidly decline.

CASE STUDY

King County Wastewater Treatment Division in Renton, Washington, installed a 1 MW molten carbonate fuel cell power plant to reduce energy costs to the treatment plant. The output is tied to a transformer to step-up voltage to 13,000 V. The fuel cell system was chosen because of its high efficiency and low emissions. This cell is operated using methane from the anaerobic digesters. King County uses the electricity produced by the fuel cells to supplement its energy needs, which also reduces the facility's power costs by 15 percent. The estimated installed cost for the MCFC system was approximately $22.8 million, including the waste heat recovery system. The waste heat recovery unit for the exhaust is sized for 1.7 million Btu per hour of waste heat. At 45% electrical efficiency and at rated heat recovery, the net thermal efficiency of the plant is expected to be around 68%. The waste heat can also be returned to the digester loop.

Large Fuel Cell Application

REFERENCES

http://en.wikipedia.org/wiki/Fuel_cell

http://www.fuelcells.org/basics/types.html

http://dnr.metrokc.gov/wtd/fuelcell/

http://www.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html#phosphoric.

Rastler, Dan. *King County Carbonate Fuel Cell Demonstration Project*, Electric Power Research Institute (EPRI), February 2005.

EPA 832-F-05-012

Office of Water

March 2006