Regenerative fuel cell in back-up power systems

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Abstract—The use of hydrogen, as a form of energy storage is becoming an increasingly viable option for energy storage in many areas of technology. Fuel cell technology is not new, having successfully been used in the NASA space program for over 40 years. Fuel cell systems based on the same principle used by NASA, the principle of self-regeneration, are becoming carefully studied subjects by many institutions. In this paper the basic set-up of the Regenerative Fuel Cell is considered along with the reasons that make this a very interesting form of power backup at remote sites and in other telecommunications applications.

Index Terms—Customer Premises Equipment, Hydrogen, Electrolysis, Regenerative Fuel Cell, and Ultra-capacitors

I. INTRODUCTION

The fuel cell is an electrochemical device that is used to generate electricity through the chemical conversion of a fuel, thus avoiding the combustion phase, and all its environmental pollutants. The fuel cell has the added advantage of having much higher conversion efficiencies than other forms of electricity production, being very reliable and extremely silent in operation [1].

The fuel cell is often compared to the battery with the reasoning that it converts stored energy to electrical energy through a chemical reaction. However the one major difference is that fuel cells can keep on producing electricity as long as there is a fuel supply. The battery on the other hand contains all its fuel inside and is unable to provide further electrical energy once these fuels are depleted.

Telecommunications equipment regularly makes use of batteries as a form of storing energy in a back-up configuration that supplies power when the primary power is cut. The ITU-T recommends that the telecommunications service should survive on occasions of mains power failures at both the customer and the exchange site [2]. The current world trend is tending to avoid the use of batteries in emergency back-up power systems and use a more environmentally friendly and reliable technology in the form of a fuel cell system.

The fuel cell system generally comprises a combination of an electrolyser, a storage device for the gases and a Proton Exchange Membrane (PEM) fuel cell. This combination forms a system that is able to recharge itself, commonly referred to as a Regenerative Fuel Cell (RFC) system. The RFC uses the electrolyser module to generate hydrogen and oxygen gases from distilled water through the process of electrolysis. The almost pure gases are then stored in a pressurised storage tank or metal hydride [1]. When power is required from the back-up source the fuel cell recombines the two gases in a reverse electrolysis reaction to generate electricity and water.

The RFC when seen as a form of back-up power is easily adaptable to the environment of the Customer Premises Equipment (CPE) with systems having the advantage of been modularised to meet a host of different requirements.

II. ELECTROLYSIS SYSTEM

The electrolysis unit functions on the principle of passing an electric current through a conductive electrolyte, with gases forming on the anode and the cathode of the unit, these gases are then captured and stored in an appropriate manner or else used as the fuel in the fuel cell process. In this system set-up, a PEM also known as a Polymer Electrolyte Membrane cell is used as the electrolysis unit. This unit is capable of generating hydrogen at pressures up to 1.33 atm and if the oxygen is kept at ambient pressure, then pressures up to 408 atm without a compressor are achievable [1].

III. HYDROGEN STORAGE

The practical implementation of the system depends on the storage of the hydrogen generated by the electrolysis module. There are a number of storage classes for hydrogen; these are low-pressure tanks, high-pressure tanks and metal hydride [1]. The most cost-effective storage is in low-pressure tanks; this however takes up too much space and is not suited to the CPE environment. The use of liquid propane tanks has become a very safe and cost effective means of storing medium volumes of hydrogen at pressure. The storage of hydrogen gas in metal hydrides is currently a very expensive option and only small amounts of gas are able to be stored, making this form of storage undesirable for CPE equipment under present technology.

IV. PEM FUEL CELL

The PEM fuel cell operates on the reverse principle of
electrolysis. With the introduction of hydrogen and oxygen to the electrodes, the reverse electrolytic reaction takes place under the effects of a catalyst and electricity is generated with water being the by-product. The catalyst, usually platinum, is bonded to the membrane; the membrane allows the protons to pass through while blocking the electrons. The electrons are then diverted through an external load.

The PEM fuel cell is available in two variations, these being the conventional PEM and the reversible PEM. The conventional fuel cell operates on the principles explained earlier, either operating in the electrolysis phase or in the fuel cell phase. The reversible fuel cell, also known as the Unitised Regenerative Fuel Cell (URFC) is a single unit that operates as either an electrolyser or as a fuel cell at any given time. It reduces the amount of components required in the system. A further study of these two cells is to take place with the viability study to be implemented.

A matter that is receiving further attention is that of the initial period after the mains power has been removed, the fuel cell requires an initial warm up period to come up to full power. A battery would come into action immediately in this instance; in the RFC system the use of another storage technology in the form of ultra-capacitors is considered for this initial start-up period. The ultra-capacitor is able to store energy by virtue of both the ionic double-layer capacitance effect and the surface redox processes, this form of energy storage is able to supply power for around one minute. Experimentation with the ultra-capacitors will determine if they are able to sustain a load for the time required in warming up the fuel cell.

V. HYDROGEN VS. BATTERY STORAGE

There are number of reasons why the trend in back-up power is moving away from traditional battery banks to fuel cell technology. These reasons involve set-up costs, life expectancy, life cycles and maintenance costs.

Often the deciding factor in CPE installations is related to cost and return on investment. The cost of batteries over the life of an installation is usually considered to exceed the cost of the entire remote system [2].

The average life expectancy of remote terminal batteries is between two and five years, with two years usually being the norm. System designers have noticed that the battery back up is very much the largest expense to the CPE system design. The advent of the fuel cell will greatly reduce the cost of the system. Although the initial costs of the RFC system are usually equal to or slightly higher than the battery installation cost, as is seen in Fig. 1 [1]. Over the lifetime of the system the fuel cell easily saves up to six times the cost of the battery equivalent.

There are additional benefits to the RFC in the form of longer periods of back up with less installation impact and lower overall cost [1]. The RFC unlike the battery is limitless in life cycles, where a battery has a life cycle dependant on the Depth of Discharge (DoD). Batteries have a shorter life cycle with deeper discharge cycles, around 800 cycles at full discharge whereas the fuel cell has almost limitless cycles at full discharge.

The maintenance costs of the fuel cell are an added advantage. The fuel cell is universally known for being almost maintenance free. It saves on the labour and equipment costs usually associated with battery maintenance. Added to this advantage is the life span of the fuel cell, batteries having a life span of around five years where the fuel cell has a life span of over twenty years.

![Comparison of Lead acid battery vs. Regenerative Fuel Cell -2kW capacity over 10 years](image-url)

**Fig.1. Cost Comparison of RFC and Batteries**

When the fuel cell is used in remote telecommunications settings such as those that are not connected to grid power supply they are often included in a photovoltaic or wind driven system. The RFC can take over the work usually performed by the battery and generator set-up of these systems. This greatly reduces the need for refuelling and the maintenance involved with this type of set-up. The added advantage is achieved by the fact that would be thieves of batteries are unable to use the fuel cell, as it requires hydrogen to fuel it and is not operational in the manner that is usually associated with battery recharging.

VI. CONCLUSION

The use of fuel cells in a regenerative fuel cell system set-up is beneficial to the CPE environment and adds versatility and cost reduction to the installation and design of backup power systems for telecommunications applications. The primary power or even solar and wind is used to generate hydrogen that is stored in medium pressure vessels for any period of time that is required. The energy can then be used as back up power when the mains fail. The RFC system is even able to operate in a stand-alone scenario powering remote sites.

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REFERENCES


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