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Improvements in Bio Fuel Power Optimization: A Review

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Abstract: An environmental and economic policy is demanding a reduction in greenhouse gases and toxic emissions. A coherent energy strategy is required, addressing both energy supply and demand, taking account of whole energy life cycle including fuel production, transmission and distribution and energy conversion, and the impact on energy equipment manufacturers and end-users of energy systems. So the number of environment and economic benefits are claimed for bio fuels. Bio fuels are important because they replace petroleum fuels. Bio ethanol is by far the most widely used bio fuel for transportation worldwide. Fuel cells could make available an opportunity to provide clean energy to India's population of one billion and reduce its energy supply-demand gap. Types of bio fuel cell are classified according to the nature of the electrode reaction and nature of the chemical reactions. The performance of fuel cells is critically reviewed and a variety of possible applications is considered. The current direction of development of bio fuel cells is carefully analysed, while considerable chemical development of enzyme electrodes has occurred, relatively little progress has been made towards the engineering development bio fuel cells. The limit of performance of bio fuel cells is highlighted and suggestions for future research directions are provided. This review paper provides a brief introduction to biological fuel cells along with their envisaged applications and improvements.

Keywords— Bio energy, Bio fuels, Fuel cells, Solar energy, Green house gas.

I. INTRODUCTION

The worldwide energy need has been increasing exponentially, the reserves of fossil fuels have been decreasing and the combustion of fossil fuels has serious negative effects on the environment because of carbon dioxide emission. For these reasons, many researchers have been working on the exploration of new sustainable energy sources that could substitute fossil fuels. Hydrogen is considered as a viable alternative fuel and "energy carrier" of future [1]. One of the solutions is to replace the existing fossil fuel energy systems by the non-fossil fuel energy systems. Bio-fuel is a one of the non-fossil fuel source. Bio fuels are important because they replace petroleum fuels. A number of environment and economic benefits are claimed for bio-fuels where a fuel cell is an electrochemical device that continuously converts chemical energy to electrical energy for as long as fuel and oxidant are supplied to it. The use of fuel cells in both stationary and mobile power applications can offer significant advantages for the sustainable conversion of energy. This challenge is even more difficult since the demand slowly shifts toward greener energies [2]. Benefits arising from the use of fuel cells include efficiency, reliability as well as economy, unique characteristics and planning flexibility and future development potential. By integrating the application of fuel cells, in series with renewable energy storage and production methods, sustainable energy requirements may be realized [4]. Renewable energy sources are derived from those natural, mechanical, thermal and growth processes that repeat themselves within our lifetime and may be relied upon to produce predictable quantities of energy when required.

A. Bio energy

Bio energy is energy derived from bio fuels. Bio fuels are the fuels produced directly or in directly from organic material including plant materials and animal waste. Today, bio fuels are predominantly produced from biomass resources. Biomass appears to be an attractive feedstock for three main reasons:

1) It is renewable resource that could be sustainably developed in the future,
2) It appears to have formidably positive environmental properties resulting in no net releases of carbon dioxide and very low sulphur content, and
3) It appears to have significant economic potential provided that fossil fuel prices increases in the future [3].

Overall, bio energy covers approximately 10% of the total world energy demand. Solar energy, which is stored in plants and animals, or in the wastes that they produce, is called biomass energy. Biomass energy is a variety of chemical energy. This energy can be recovered by burning biomass as a fuel [4]. Traditional unprocessed biomass such as wood, charcoal and animal dung accounts for the most of this and represents the main source of energy for a large number of people in developing countries who use it mainly for cooking and heating.

B. Bio fuels

Bio fuels are gaseous, liquid, or solid fuels that are produced from raw biological material or biomass (plants,

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sewage, dry waste, cane sugar, wood pulp etc.) through combustion or fermentation. Currently biomass accounts for approximately 15% of global energy use. In less developed countries, biomass remains an important energy resource, averaging around 38% of energy use and rising to 90% in some countries. Bio-fuels that have been identified as potential fuel for fuel cells are landfill gas, anaerobic digester gas, biomass gasification, bio diesel, and ethanol etc.

C. Hydrogen fuel cell

Hydrogen is an energy carrier that can be used to store, move and deliver energy produced from other sources. It's the simplest element on the earth and the most abundant element in the universe; but despite its simplicity and abundance, hydrogen doesn't occur naturally as a gas on earth. It is always combined with other elements for example water is a combination of hydrogen and oxygen. Hydrogen is also found in many organic compounds, notably the "hydrocarbons" that make up fuels such as gasoline, natural gas, methanol and propane etc. To generate electricity using pure hydrogen must first be extracted from a hydrogen containing compounds then it can be used in a fuel cell. These fuel cells are usually classified according to the electrolyte that is used i.e. alkaline, proton exchange membrane, phosphoric acid, molten carbonate, solid oxide etc. [5]. PEM fuel cell is also sometimes referred to as a polymer electrolyte fuel cell. PEM fuel cells are the serious candidate for small-scale distributed stationary power generation [6]. Stationary applications range from in-home power and heat generation (output starting at 2KW) to heat and power supply for entire residential areas means of heat and power block units (with outputs in the MW range). That's why, PEM fuel cell is used in small scale power generation. Korneel et. al. presented a discussion on Micro fuel cells that how bacteria use an anode as an electron acceptor and to what extent they generate electrical output. The MFC technology is evaluated relative to current alternatives for energy generation [7].

1) Polymer electrolyte membrane fuel cells

Polymer Electrolyte Membrane fuel (PEM) cells also called proton exchange membrane fuel deliver high power density and offer the advantages of low weight and volume compared with other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air and water to operate and do not require corrosive fluids like some fuel cells. They are typically fuelled with pure hydrogen supplied from storage tanks or on-board reformers [8].

PEM fuel cells operate at relatively low temperatures around 80°C. Low temperature operation allows them to start quickly (less warm up time) and results in less wear on system components, resulting in better durability. However, it requires that a noble metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons adding to system cost. The platinum catalyst is also extremely sensitive to CO poisoning making it necessary to employ an additional reactor to reduce CO in the fuel gas, if the hydrogen is derived from an alcohol or hydrocarbon fuel. Higher density liquid fuels such as methanol, ethanol, natural gas, liquefied petroleum gas and gasoline can be used for fuel but the vehicles must have an on board fuel processor to reform the methanol to hydrogen. This requirement increases costs and maintenance. The reformer also releases carbon dioxide (a green house gas), though less than that emitted from current gasoline powered engines [8].

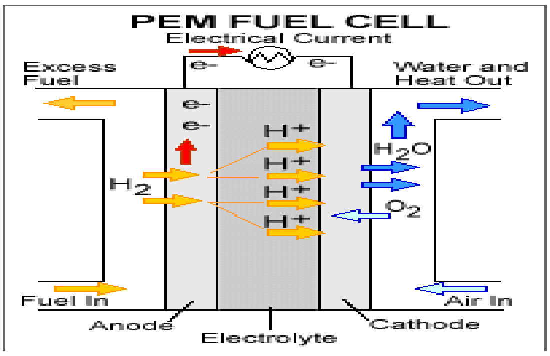

Fig. 1. Proton exchange membrane fuel cell

The Proton Exchange Membrane fuel cell uses a thin, permeable polymeric membrane as the electrolyte as shown in Figure 1. The membrane is very small and light and in order to catalyse the reaction, platinum electrodes are used on either side of the membrane. Within the PEM fuel cell unit, hydrogen molecules are supplied at the anode and split in to hydrogen protons and electrons. The protons pass across the polymeric membrane to the cathode while the electrons are pushed round an external circuit in order to supplied at the anode and split in to hydrogen protons and electrons. The protons pass across the polymeric membrane to the cathode while the electrons are pushed round an external circuit in order to produce electricity. Oxygen (in the form of air) is supplied to the cathode and combines with the hydrogen ions to produce water. The efficiency of a PEM unit usually reaches between 40% to 60% and the output of the system can be varied to meet shifting demand patterns. Typical electric power is up to 250 kilo-watt. Bilal et. al. introduced the hydrogen and PEM fuel cells area and also investigated the possibility to produce hydrogen from solar source to supply a fuel cell [9].

Generally, there are three main application fields for a PEMFC system such as transportation, stationary and portable applications. The development direction of PEMFCs in each nation is bound up with their social and industrial environment as well as their structure of energy supply and demand [10]. In addition, PEM fuel cells are often compact and lightweight units. As a result of these characteristics, PEM units tend to be the best candidates for cars, buildings and smaller stationary applications. As the electrolyte is a solid rather than a liquid, the sealing of the anode and cathode gases is far easier and this in turn

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makes the unit cheaper to manufacture than some other types of fuel cell. Jang Ho. Wee et.al introduced and discussed the challenges and some of the latest research on the application test of PEMFC to real systems such as transportation, residential power generation and portable computers [11]. Thounthong et. al presented the utilization as a super capacitor as auxiliary power source in a distributed generation system, composed of a polymer electrolyte membrane Fuel cell (PEMFC) as the main energy source. The very fast power response and high specific power of a super capacitor can complement the slower power output of the main source to produce the compatibility and performance characteristics needed in a load [12].

2) Direct methanol fuel cells

The technology behind Direct Methanol Fuel Cells is still in the early stages of development, but it has been successfully demonstrated powering mobile phones and laptop, computers-potential target end uses in future years. DMFC is similar to the PEMFC in that the electrolyte is a polymer and the charge carrier is the hydrogen ion (proton). However, the liquid methanol (CH_3OH) is oxidized in the presence of the water at the anode generating CO_2, hydrogen ions and the electrons that travel through the external circuit as the electric output of the fuel cell. The hydrogen ions travel through the electrolyte and react with oxygen from the air and the electrons from external circuit to form water at the anode completing the circuit.

3) Alkaline fuel cells

Alkaline Fuel Cells (AFC) are one of the most developed technologies and have been used since the mid 1960’s by NASA in the Apollo and Space Shuttle programs. The fuel cells on board these spacecraft provide electrical power for on-board systems, as well as drinking water. AFCs are among the most efficient in generating electricity at nearly 70%. Alkaline fuel cells use an electrolyte that is an aqueous solution of potassium hydroxide (KOH) retained in a porous stabilized matrix. The concentration of KOH can be varied with the fuel cell operating temperature, which ranges from 65°C to 220°C. The charge carrier for an AFC is the hydroxyl ion (OH-) that migrates from the cathode to the anode where they react with hydrogen to produce water and electrons as shown in Figure 2. Water formed at the anode migrates back to the cathode to regenerate hydroxyl ions. Therefore, the chemical reaction at the anode and cathode in the fuel cell produces electricity and by-product heat.

4) Phosphoric acid fuel cell

Phosphoric acid fuel cells were the first fuel cells to be commercialized. Developed in the mid- 1960s and field-tested since the 1970s, they have improved significantly in stability, performance and cost. Such characteristics have made the PAFC a good candidate for early stationary applications. Iordanidis et.al investigated the concept of sorption-enhanced steam reforming of bio-oil/ biogas for

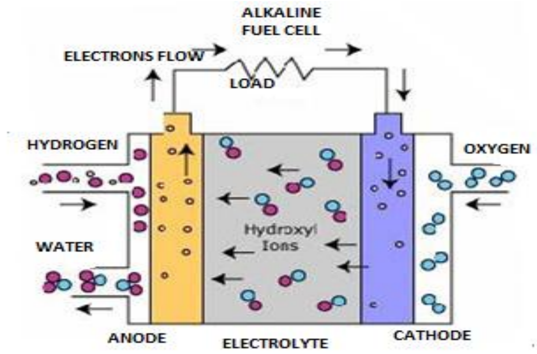

Fig. 2 Alkaline fuel cell

electricity and heat generation by phosphoric acid fuel cells. The process is modelled using SIMCI Pro II process simulator [13].

The PAFC uses an electrolyte that is phosphoric acid that can approach 100% concentration. The ionic conductivity of phosphoric acid is low at low temperatures, so PAFCs are operated at the upper end of the range 150ºC-220ºC. The charge carrier in this type of fuel cell is the hydrogen ions. This is similar to the PEFC where the hydrogen introduced at the anode is split into its protons and electrons. The protons migrate through the electrolyte and combine with the oxygen, usually from air, at the cathode to form water as shown in Figure 3.

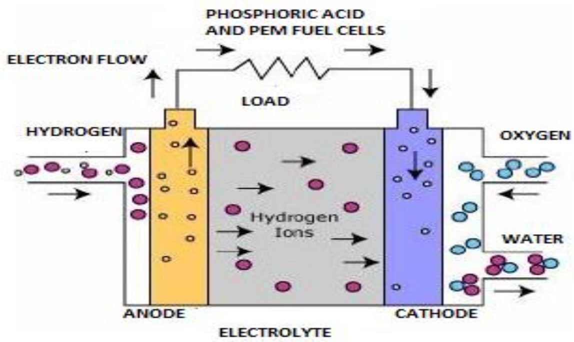

Fig. 3: Phosphoric acid fuel cell

The electrons are routed through an external circuit where they can perform useful work. This set of reactions in the fuel cell produces electricity and by-product heat.

5) Molten carbonate fuel cells

Molten Carbonate Fuel Cells (MCFC) are in the class of high temperature fuel cells. The higher operating temperature allows them to use natural gas directly without the need for a fuel processor and have also been used with low fuel gas from industrial processes and other sources and fuels. Developed in the mid-1960s, improvements have been made in fabrication methods, performance and endurance. MCFCs work quite differently from other fuel cells. These cells use an electrolyte composed of a molten mixture of carbonate salts. Two mixture are currently used i.e. lithium carbonate and potassium carbonate, or lithium carbonate and sodium

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carbonate. To melt the carbonate salts and achieve high ion mobility through the electrolyte, MCFCs operate at high temperature (650ºC). When heated to a temperature of around 650ºC, these salts melt and become conductive to carbonate ions (CO_3^{2-}). These ions flow from the cathode to the anode where they combine with hydrogen to give water, carbon dioxide and electrons as shown in Figure 4. These electrons are routed through an external circuit back to the cathode, generating electricity and by-product as heat.

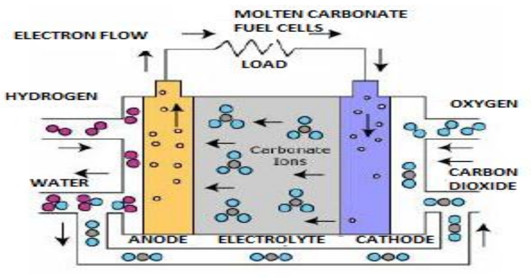

Fig. 4 Molten carbonate fuel cell

6) Solid oxide fuel cell

The solid oxide fuel cell (SOFC) is best suited for stationary applications. The system requires a high operating temperature of 1000°C. Newer systems are being developed that run at about 70%. A significant advantage of the SOFC is leniency to fuel. Due to high operating temperature, hydrogen is produced through a catalytic reforming process. This eliminates the external reformer to provide hydrogen as shown in Figure 5. Carbon monoxide, a contaminant in the PEM systems, is a fuel for the SOFC. In addition, the SOFC system offers a fuel efficiency of 60% one of the highest among fuel cell. Higher stack temperatures demand exotic materials, which add to manufacturing costs. Heat also presents a challenge for longevity and reliability because of increased material oxidation and stress. High temperatures enable co-generation by running steam generators to improve overall efficiency.

Several variations of the fuel cell systems have merged. The PEM is the most developed system and is aimed for vehicles and portable power units. The alkaline system which uses a liquid electrolyte is the preferred fuel cell for aerospace applications including the space shuttle.

Molten Carbonate Phosphoric Acid and Solid Oxide Fuel Cells are reserved for stationary power generation. The Solid Oxide is the least developed but has received renewed attention due to new cell materials and improvements in stack designs.

In this paper, the discussion on improvements of bio fuel power optimization is done in it. The literature reviews are presented in Section II followed by Conclusion in Section III.

II. RESEARCH REVIEW

The papers most relevant to the improvements addressed in this work are on the optimal design and operations of the process supply chain. Some recent work specifically focused on bio fuel power generation supply chains is reviewed below:

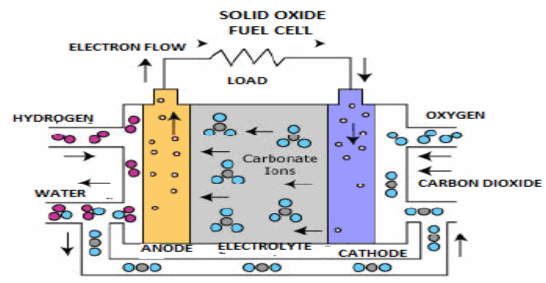

Fig. 5 Solid oxide fuel cell

Naguyen et.al. compared and discussed the performance of different micro fuel cells published recently in the literature. Finally, this review has been given an outlook on possible future development of micro fuel cell research [8]. Since micro fuel cells are defined as being fabricated with micro technology and having micro structures, batch fabrication of micro fuel is desired. Similar to the microelectronic devices and micro electro mechanical systems (MEMS), batch fabrication would decrease the cost and make complex fuel cells with integrated sensors possible. This review shows that high performance can be achieved by careful design of delivery, water/ temperature management and current collector and by minimizing the contact resistance between parts. Batch fabrication also allows the integration of temperature and humidity sensors.

Kapdan et. al. presented the review of bio hydrogen production from waste materials and also summarized bio-hydrogen production from waste materials. Types of potential waste materials, bio-processing strategies, microbial cultures to be used, bio-processing conditions and the recent development are also discussed with their relative advantages [1].

Nevin et. al. examined the power output and columbic efficiencies from biofilms of geobactor sulfurreducens comparable to mixed community microbial fuel cells. It has been noted that mixed communities typically produce more power in microbial fuel cells than pure cultures. In order to examine bio films on the anode surfaces, the fuel cells were disassembled and the carbon cloth anode was removed without touching its surface. Anodes were dipped in freshwater medium to remove any loose cells or debris that was not part of the attached bio film [6].

Mata et.al. reviewed the current status of microalgae use for bio diesel production, including their cultivation, harvesting and processing. The microalgae species most used for bio diesel production are presented and their main advantages described in comparison with other available biodiesel feed stocks. Producing algal biodiesel requires large-scale cultivation and harvesting systems, with the challenging of reducing the cost per unit area. It is therefore clear that a considerable investment in technological development and technical expertise is still needed before algal biodiesel is economically viable and can become a reality. This should be accomplished together with strategic planning and political and economic support [14].

Pant et. al. reviewed the various substrates that have been explored in MFCs so far, their resulting performance, limitations as well as future potential substrates. The review summarized the various substrates that have been used in MFCs for current production as well as waste treatment [15].

You et. al. addressed the optimal design and planning of cellulosic ethanol supply chains under economic, environmental, and social objectives. The economic objective is measured by the total annualized cost, the environmental objective is measured by the life cycle for green house gas emissions, and the social objective is measured by the number of accrued local jobs. The proposed approach is illustrated through two case studies for the state of Illinois [16].

Misron et. al. presented the performance of an electrical generator using bio fuel and gasoline blends of different composition as fuel in a single cylinder engine. The effect of an optimized blend ratio of bio-fuel with gasoline on engine performance improvement and thereby on the electrical generator output is studied. The investigations were performed on a portable generator used in palm tree harvesting applications. Author concluded that the engine performance increases compared to using 100% gasoline as fuel for a typical load condition with certain bio-fuel and gasoline blends, especially when high load torque is required [10].

Pooja et. al. presented a model of small electricity energy generation based on solar-hydrogen fuel which resolves the long term storage problems of energy. In a solar-hydrogen energy system, some photovoltaic array would provide current electricity demand while others would be used to produce hydrogen for storage and later use in fuel cells to generate electricity. The paper also presented the design of the system that is used between solar-hydrogen fuel system to generate non-stop electricity i.e., independent on weather climate or sun [17].

III. CONCLUSION

Despite the large variation in life cycle analyses results from the literature for green house gas savings with alternative bio fuel system, it is possible to draw a few robust conclusions. Obviously, the savings of green house gas with bio fuels will be higher likely when biomass yields are high. Biomass is converted to fuel efficiently, and the resulting biofuel is used efficiently. This paper has shown that by the proper application of optimization techniques and process systems engineering methodologies. Finally the goal of zero discharge requires the development of more efficient and cheaper waste water technologies even though for certain processes it can be obtain at the present degree of development. There are many additional environmental, technical, economic, social, institutional, political and other factors to be considered in the implementation of bio fuel projects or programs. Projects and programs that have positive attributes in multiple dimensions are, obviously, most desirable.

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