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DIPLOMA PROJECT

DESIGN OF A FUEL CELL SYSTEM FOR THE STATIONARY GENERATION OF ENERGY

M/990

BY

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Summary

Through this project we will describe the fuel cell principles of operation and we will see the history of it. The efficiencies that can be obtained by a fuel cell will be examined too. The principles and various types of fuel cells will be exemplified. As the fuel cells use hydrogen or other gases for fuel, we will see how the hydrogen can be produced, stored and supplied to the cells, as well as how the other gases (like natural gas) are used.

In addition through this project we will see the accessories of a fuel cell plant and how they are used in order to take in advance the waste heat that the cells produced. A comparison of the cost of a certain Cypriot family house for heating and cooling by the commonly used means with the possibility of replacing them by a fuel cell plant, will be examined.

Finally we concluded that fuel cells are considered to be the most promising future technology for generating useful energy as they directly convert the chemical energy stored in a fuel into electricity and heat.

The main conclusion of this project is that the fuel cells can not be used at this moment for residential use in Cyprus. The cost is so high and interest will be vested only if a large plant of above the 1MW is installed to supply electricity and heat to a group of house (200 family houses). Also through this project we concluded that the fuel cell is not a renewable method of producing electricity but its importance is the upper higher efficiency that can be reached. Along the project we realized that the limitations are such so as the direct applicability of a fuel cell for residential use at the moment is not possible for any house any where in the world. Apparently the technological evolution of fuel cell and photovoltaic is directly related and if any time in the foreseeable future their cost is drastically reduced then a totally renewable stationary generation of energy will be a reality. The strict sense of the design aspect of the project has been materialized only in assessing the possible cost of an imaginary system otherwise the specifics would have been carried out in full detail. It must be stated that the breath and depth of the terminology, process identification, energy assessment, operational mechanism, relevant governing equations, cost and system specifics were not familiar to us so as a vast amount of time was invested in comprehending the above. Furthermore no single source of information was available and lots of information was obtained by direct contact with fuel cell companies abroad.

The author ....

Stavros Neos

Acknowledgements

Now, when this project comes to its end, to my mind comes all the time I have spent to come up to this point, the difficulties I have faced and the pleasure of partial success when everything was set and done.

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Thank you.

The author……

Stavros Neos

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Abbreviations

AC	Alternative Current
AFC	Alkaline Fuel Cell
BOP	Balance of Plant
CHP	Combine heat and power
CPO	Catalytic Partial Oxidation
DC	Direct Current
DIR	Direct Internal Reforming
DMFC	Direct Methanol Fuel Cell
EMF	Electromotive Force
EV	Engine Vehicle
FCV	Fuel Cell Vehicle
GDE	Gas Diffusion Electrode
ICE	Internal Combustion Engine
IIR	Indirect Internal Reforming
MCFC	Molten Carbonate Fuel Cell
PAFC	Phosphoric Acid Fuel Cell
PEMFC	Proton Exchange Membrane Fuel Cell
PTFE	Polytetrafluoroethylene
YSZ	Yttria Stabilized Zirconia
ZAFC	Zinc/Air Fuel Cell

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Introduction

Several National Laboratories, Academic Institutions and manufacturing companies of fuel cells are working closely with industry affiliates to overcome critical technical barriers to fuel cell development. These barriers include the development of low cost, high performance and efficiency fuel processing technology.

The fuel cell is a device that converts the chemical energy of a fuel into usable electricity and heat without combustion as an intermediate step. Fuel cells are similar to batteries in that both produce a DC current by means of an electrochemical process and are the reverse action of that which takes place in an electrolyser. In a fuel cell two electrodes, an anode and a cathode, are separated by an electrolyte. The reactants gases are stored externally and the fuel cell can operate as the reactants gases are supplied to it. At the anode, hydrogen atoms are split by a catalyst into hydrogen ions (protons) and electrons. The hydrogen ions then travel through the electrolyte to the cathode. Simultaneously, the electrons move through an external circuit to a load and then to the cathode. There the oxygen, hydrogen ions and electrons combine to form water. Fuel cells are combined into groups called stacks to achieve a useful voltage and power output.

The engineers are trying to develop a fuel cell that can compete the traditional methods of producing electricity. That's why there are so many types of fuel cells at the present. The most widely used are:

- Proton Exchange Membrane Fuel Cell
- Alkaline Fuel Cell
- Direct Methanol Fuel Cell

- Phosphoric Acid Fuel Cell
- Molten Carbonate Fuel Cell
- Solid Oxide Fuel Cell

The main different of them is the type of electrolyte that they use.

The so great interest of the engineers for the fuel cell technology is due to the advantages of it. Fuel cells are high modular and scalable, with no moving parts, which make them inherently, quiet and virtually maintenance free. Fuel cells have the lowest emissions of any hydrocarbon fueled generation technology, and only the photovoltaics are cleaner. The only significant substances that any operating fuel cell produces are water and carbon dioxide. The main reason that engineers interest a lot about the fuel cell technology is the high efficiencies that can be achieved by fuel cells. The ideal fuel cell efficiency is much greater than of the Carnot limit of a heat engine. Also the engineers have the opportunity to take in advance the heat that is rejected to the environment, especially at high temperature fuel cells.

Fuel cells operate best on pure hydrogen, especially the low temperature fuel cells. Therefore there is the need to produce the hydrogen. The two primary types of producing hydrogen are the steam reforming and partial oxidation reforming. Steam reformers have higher efficiencies but partial oxidation reformers are simpler. The low temperature fuel cells required pure hydrogen to run effectively, impurities in the reformer product gas stream must be removed. This can be achieved with water gas shift reactors.

Nowadays many companies proceed to the stage of producing and selling fuel cells. But almost all of them don't have the ability to meet any costumer need for residential use. They sell demonstration packages or the fuel cells that are available, are just in the testing stage or are produced only for a certain target in order to investigate them. For high temperature fuel cells (large stationary fuel cells) the above is not valid. An example is the Fuel Cell Energy Inc. and UTC Fuel Cell. FCE has built a factory capable of manufacturing 50MW of fuel cells per year and has already taken 12MW of orders for its DFC 300A (MCFC). It already has installed about 30 of the units worldwide and expects to double that number over the next few years. UTC Fuel Cells has had a 200kW phosphoric acid fuel cell on the market for over 10 years and has deployed more than 200 systems in 19 countries.

Through this project will examine in detail the operation principles, the efficiencies, the types, the thermodynamic point of view of fuel cells, what fuels are used, how can be produced-stored and supplied to a fuel cell. We will examine also the possibility of using a fuel cell for residential use in Cyprus, the advantages and disadvantages of them and the why are considered to be the most promising future technology of producing electricity.