Economics of Grid-Connected PEM Fuel Cells

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Abstract—**In this panel presentation, an assessment of the economical benefits of grid-connected PEM fuel cells is presented. A calculation of the cost of electricity generated from fuel cell is given. A sensitivity analysis procedure is proposed to determine what goals need to be achieved to make fuel cells competitive with conventional power generation sources.**

I. Introduction

Fuel cells have the potential of providing clean and efficient power. Their nearly silent operation and scalability make them particularly attractive for distributed generation applications. However, they are not yet competitive with traditional forms of energy production. Currently, improvements in fuel cell technology have focused on the cost of fuel cells. While it is clear that lowering fuel cell costs is an important goal, there are many other areas in fuel cell technology that can be improved on. Some of the challenges associated with fuel cell research and development include: improving efficiency, reducing component and system cost, and increasing reliability and lifetime of the entire system.

Previous work related to fuel cell economic research has focused mostly on determining the cost of electricity (COE). An evaluation of the COE is necessary to determine whether an installation is cost effective and to compare a particular installation with different forms of energy production. A sensitivity analysis of the COE will also determine the amount of change in the COE that would result from changing each individual parameter. This will help determine what areas of fuel cell research should be focused on. An assessment of the cost associated with environmental damage due to the use of fossil fueled energy is also needed to obtain a fair economic comparison between the fossil fueled energy generation and the fuel cell energy.

This panel presentation will evaluate the economic performance of the proton exchange membrane fuel cells (PEMFCs), based not only on changes in fuel cell costs but also on changes in fuel cost, maintenance cost, capital cost, efficiency, yearly operating hours, and lifetime of the fuel cell. The results of a graphical user interface (GUI) program, which combines a calculation of the COE, a sensitivity analysis, and an environmental damage calculation, for the PEM fuel cells will be presented. These calculations include maintenance costs, savings from reduced environmental damage, and an annual capital cost, which is based on replacing certain components of the fuel cell installation at the end of its lifetime. The results of an economic study and a sensitivity analysis will also be presented. The economic study will evaluate the net profit (or loss) of the fuel cell installation. The sensitivity analysis will look at the effect of the variation of each parameter of interest on the COE in an attempt to find what parameter values would result in the installation having no profit or loss (breaking even), or resulting in a COE that is equal to a user defined value.

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II. Cost of Fuel Cell Generated Electricity

In this study, the COE for hydrogen fueled PEM Fuel Cells is evaluated. The study incorporates a savings associated with a reduction in environmental damage associated with using hydrogen generated from non-fossil fuel sources.

The annual cost of electricity generated by the fuel cell can be defined as

$$COE = (ACC + AFC + AMC - S_{en})/AEP$$

Where, *ACC* is the annual capital cost,
AFC is the annual fuel cost,
AMC is the annual maintenance cost,
S_{en} is the environmental cost associated with using fossil fuels
AEP is the annual energy produced by the fuel cell.

III. Economic Analysis

In addition to calculating an overall COE for a fuel cell unit, an economic analysis is also necessary in order to determine if there is a net profit or loss, without the need to compare to other forms of electricity generation. Three different parameters are calculated in the economic analysis: PayBack Period (PBP), Net Present Value (NPV), and Benefit/Cost Ratio (BCR).

The payback period is an estimate of the number of years it will take to pay for the fuel cell. It is a relatively quick, but only an approximate estimation of the economic viability of the installation.

The Net Present Value (NPV) is the present value of future incomes. It is an important parameter in determining the value of the installation. The importance of NPV relating to fuel cell energy is the fact that yearly income from the fuel cell will be distributed over several years. Even if all the payments were assumed to be equal, the NPV of each payment would be different and would decrease each year.

The benefit to cost ratio (BCR) is simply the ratio of dollar amount of benefits to the dollar amount of costs.

In determining the overall recommendation for the installation, only the NPV and the BCR are considered. If the NPV is positive and the BCR is greater than unity a positive recommendation will be given, indicating there will be a profit from installing the fuel cell.

A break even analysis can also be conducted when one is uncertain of the possible values a parameter can take on. There will be an interest in determining the set of parameter values for which an investment alternative is justified economically and the set of values for which an alternative is not justified. Different parameters can be varied from their base case in an effort to find the value they would have to have in order for the fuel cell to have a NPV = 0 (break even in the sense that there is no profit or loss). The parameter values can also be adjusted in order to find what they would have to be in order to obtain a specified COE. The parameters which can be examined include: fuel cost, maintenance cost, capital cost, efficiency, yearly operating hours, lifetime of fuel cell, and price of electricity per kWhr paid by utility.

A sensitivity analysis is conducted when one is reasonably sure of the possible values a parameter can take on, but uncertain of their chances of occurrence. It is a way to calculate the sensitivity of the "measure of merit" (for example the COE) to various parameter values.

Sensitivity analysis can be useful in determining the amount of change in the COE vs. the change in any (or a combination) of the variables given above. Such analysis can be done in an effort to show a realistic value that the variables would have to have in order to find an acceptable COE.

Currently fuel cells are not capable of achieving a favorable COE. Therefore, it is likely that they will have to improve in more than one way, e.g. improving both efficiency and lowering capital costs, in order to achieve an acceptable COE. Three dimensional graphs showing the effect of variation of 1) projected fuel cell efficiency and capital cost on the cost of electricity and 2) projected fuel cell efficiency and fuel cost on the cost of electricity generated by PEMFCs are given in Figs. 1 and 2, respectively. As noted from these figures, the cost of electricity generated from PEMFCs is expected to come down rapidly with advances in the fuel cell technology, resulting in higher fuel cell efficiency and capital cost and fuel cost.

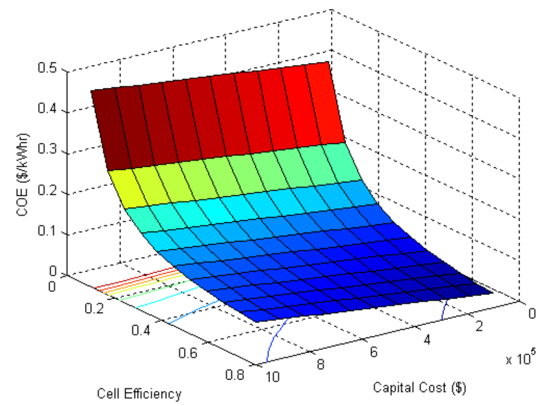

Fig. 1. Plot of COE vs. efficiency and capital cost for PEMFC.

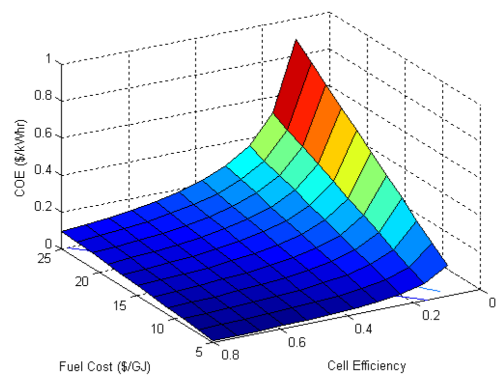

Fig. 2. Plot of COE vs. fuel cost and cell efficiency.

IV. COMMENTS AND CONCLUSIONS

It is expected that hydrogen from non-fossil, renewable energy sources will become technically, economically and ecologically important in the next 20 years. It has also been predicted that the cost of hydrogen and natural gas will merge by the year 2030. This is due to an increase in natural gas prices due to scarcity of supply and a decrease in hydrogen prices due to increased research and development in the production, storage and transportation of hydrogen.

One factor that significantly increases the value of fuel cells is subsidy, (i.e. federal, state, and utility subsidies). When these factors are factored in, the fuel cell generated COE and NPV would improve significantly, i.e. the COE would be lower and the NPV would increase. Most incentives available to the general public concern wind, PV, hydro, and biomass. Fuel Cells are currently not listed in many financial incentives. However, there are several types of tax credits available for non-fossil fueled power plants, and currently large fuel cell projects are significantly funded through government grants.

Another factor that needs to be considered in the economic evaluation of fuel cell distributed generation systems is the reduction of costs associated with their installations. Distributed Generation will result in less transmission losses, deferment (or elimination) of the need to install new transmission lines, and a reduction in the use of older less efficient power plants currently being used during peak demand times. Fuel cells are especially attractive for distributed generation because they are quiet, and scalable, and a natural gas infrastructure already exists. The heat from a fuel cell can also be used to heat buildings, resulting in a high overall efficiency.

There will also likely be a decrease in the capital costs associated with fuel cells in the near future as a result of technological advances. In order for the price of fuel cells to fall significantly, an effort will have to be made to mass produce fuel cells. However, the price of fuel cells must fall before there will be a large enough demand to justify mass production. This dilemma is faced not only for the price of the fuel cell stacks, but is also seen in the fuel, especially if it is an uncommonly used fuel, such as hydrogen.