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ScienceDirect
Journal of Power Sources 165 (2007) 300–306
JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

Economic analysis of a combined heat and power molten carbonate fuel cell system

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Received 10 November 2006; accepted 18 December 2006
Available online 22 January 2007

Abstract

Fuel cells can be attractive for use as stationary combined heat and power (CHP) systems. Molten carbonate fuel cell (MCFC) power plants are prime candidates for the utilization of fossil based fuels to generate high efficiency ultra clean power. However, fuel cells are considerably more expensive than comparable conventional technologies and therefore a careful analysis of the economics must be taken. This work presents analysis on the feasibility of installing both a FuelCell Energy DFC® 1500MA and 300MA system for use at Adams Thermal Systems, a manufacturing facility in the U.S. Midwest. The paper examined thoroughly the economics driving the appropriateness of this measure. In addition, a parametric study was conducted to determine scenarios including variation in electric and natural gas rates along with reduced installation costs.

Keywords: Combined heat and power (CHP); Molten carbonate fuel cells; Manufacturing; FuelCell Energy

1. Introduction

The direct conversion of chemical into electrical energy with high efficiency, no noise or hazardous emissions has been an engineer's dream since the discovery of the fuel cell concept in the 19th century [1]. Fuel cells of today have many technological advances including: high fuel efficiency, ultra-clean emissions, improved reliability, quiet operation, scalability, operation from readily available fuels and the ability to provide both electricity and heat [2]. Because of these reasons, fuel cells can be attractive for use as stationary combined heat and power (CHP) systems. Molten carbonate fuel cell (MCFC) power plants are prime candidates for the utilization of fossil based fuels to generate high efficiency ultra clean power. However, these systems are considerably more expensive than comparable conventional technologies and therefore a careful analysis of the economics must be taken.

Previous assessments of MCFC technologies have focused on the commercial viability of these technologies in generating electricity. As expected, these analyses revealed that the primary barrier towards increased market acceptance has been capital costs, which in some cases can lead to payback periods in excess of the life of the plant [3]. Based on historical cost trends and increased market penetration of MCFC technologies, these barriers will become less pronounced [4]. As a result of expected decreases in capital costs, analyses are often carried out utilizing a fixed utility structure and allowing the capital costs to fluctuate [5]. This can provide a forecast of the future potential of MCFC technologies. Further, analyses are often based upon areas in which the potential application of MCFC technologies is the greatest. That is, areas with high utility rates and emissions penalties. One area that quite often gets overlooked for the application of fuel cell technologies is the U.S. Midwest [2]. Here, utility rates are significantly lower and emissions penalties are traditionally less severe. The following provides an analysis of installing a FuelCell Energy MCFC system at a manufacturing plant in the U.S. Midwest.

FuelCell Energy has developed a unique MCFC termed direct fuel cell (DFC®). The DFC® design incorporates an internal reforming feature that allows utilization of a hydrocarbon fuel directly in the fuel cell without requiring any external reforming reactor and associated heat exchange equipment. This approach upgrades waste heat to chemical energy and thereby contributes to a higher overall conversion efficiency

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doi:10.1016/j.jpowsour.2006.12.053

Nomenclature

ATS	Adams thermal systems
CE	corrected efficiency (%)
CHP	combined heat and power
CPO	corrected power output (kW)
CS	cost savings ($ year^{-1})
DFC	direct fuel cell
FU	fuel usage (kW)
H	local elevation (435 m)
HR	heat recovered (kW)
IC	implementation cost ($)
MCFC	molten carbonate fuel cell
PEL	plant electric load (kW)
PL	part load ratio (%)
RE	rated efficiency (47%)
RER	rated energy recovery, 410.3 kW (1,400,000 Btu h^{-1})
RFC	rated fuel consumption, 2126.1 kW (7,254,000 Btu h^{-1})
RPO	rated power output (1000 kW)
RWU	rated water usage, 0.3155 L s^{-1} (5 gpm)
SP	simple payback period (years)
T_{amb}	local ambient temperature (°C)

of fuel energy to electricity with low levels of environmental emissions [6]. FuelCell Energy has developed direct fuel cells in three capacities: DFC® 300MA, DFC® 1500MA and DFC® 3000MA with capacities of 250, 1000 and 2000 kW, respectively.

This work presents analysis on the feasibility of installing both a DFC® 1500MA and 300MA system for use at ATS, a manufacturing facility in the U.S. Midwest. The paper thoroughly examined the economics driving the appropriateness of the feasibility of DFC® power systems. Significant economic parameters analyzed included: electrical savings, natural gas costs, maintenance savings, emissions savings and implementation costs. In addition, a parametric study was conducted to determine scenarios including variation in electric and natural gas rates along with reduced installation costs.

2. Baseline power systems

ATS is a South Dakota manufacturer of engine cooling systems for off and on-highway vehicles [7]. Housed in a 12,077 m^2 (130,000 ft^2) manufacturing facility, production occurs 8760 h year^{-1} and as a result, the facility consumes a considerable amount of resources including both electricity and natural gas [7]. The following section summarizes electric, natural gas, water and sewer usage over the course of one calendar year. These results were critical in the analysis of the feasibility of a CHP fuel cell system installation at the facility.

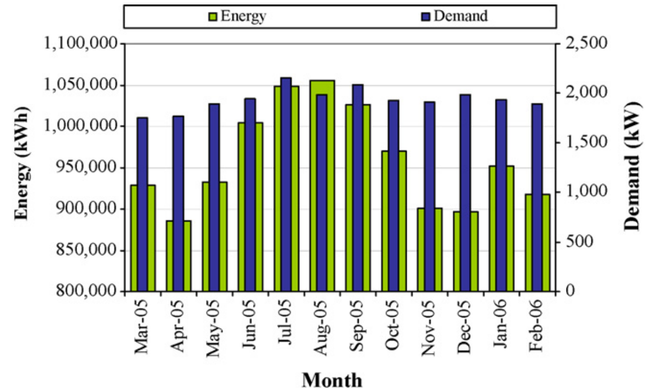

Fig. 1. Electrical summary.

2.1. Electric system

Electrical consumption can be attributed to such items as: lighting, air compressors, fans, pumps, cooling and process equipment. Demand rates are $8.50 kW^{-1} with energy rates averaging 3.2 cents kWh^{-1}.

Electrical demand and usage along with the associated charges, fees and taxes were obtained from billing statements for the months of March 2005 through February 2006 [7]. During the survey period, the facility consumed 11,516,318 kWh year^{-1} with a maximum demand reaching 2156.76 kW in July. The total charges incurred by the facility were $614,622 year^{-1}. Monthly energy and demand amounts were then plotted as shown in Fig. 1.

Fig. 1 shows a relatively consistent year-round demand slightly peaking in the summer, which gives support to some space cooling at the facility. Conversely, the energy usage varies considerable and peaks during summer months. This tends to show that the facility has varying production throughout the year, where times of increased production in the summer are joined by increased electrical energy usage.

2.2. Natural gas system

As discussed previously, the facility utilizes natural gas for a variety of heating processes. A survey of significant natural gas consuming equipment was analyzed to find prospective uses for waste heat generated from the anticipated fuel cell system.

Natural gas information was obtained from the facility for a period from May 2004 through April 2005 [7]. Due to availability of the information, this period does not coincide with electric information. This is not problematic since only a representative overall natural gas cost is needed.

The facility consumed 64,506,076 MJ year^{-1} (611,432 therms year^{-1}) during the survey period with an average value of 5375506.3 MJ month^{-1} (50,953 therms month^{-1}). The facility was charged $380,396 year^{-1} for the purchase and use of natural gas. An overall average energy rate was obtained in the amount of $0.0059 MJ^{-1} ($0.62 therm^{-1}). This rate was used for cost savings analyses.