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Fuel cells for distributed power generation

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Abstract

Deregulation has caused a major change in power distribution in the USA. Large central power stations are being and will continue to be replaced by smaller, distributed power generation sources of less than 20 kW. Fuel cells, specifically molten carbonate fuel cells (MCFCs), are best suited to serve this need. Small turbines cannot achieve the efficiency or environmental friendliness of MCFCs in this power range. This paper discusses the goals of M-C Power Corporation and the advantages of its IMHEX® MCFC technology. M-C Power's factory, demonstration testing program, and its market-entry power plant are also described, as are its commercialization strategy and schedule.

Keywords: Fuel cells; Power generation; Distribution

1. Introduction

Twenty years ago, all electric power in the USA was generated at large central power stations. Twenty years from now, much of this power will be generated in small power units that are distributed throughout the service grid. Because such units are located closer to the customer, they better meet his needs. This 'distributed power generation' (DG) concept is growing rapidly in the USA.

Deregulation is the major cause for this change. Price competition can no longer support the huge, multi-billion dollar capital investment in central power stations, especially when capital depreciation accounts for half the cost of electricity (COE). When 1000 MW is installed to solve a 5-10 year growth projection, depreciation exceeds half of the COE for much of the growth projection period.

Furthermore, DG has many associated cost benefits: T&D credits, power loss credits, thermal credits, and fuel diversity, to name a few. These benefits are seldom credited to DG. The tide is, however, changing. The Los Angeles Department of Water and Power has recently estimated these credits at up to 7¢ per kWh, a substantial benefit for DG.

2. Molten carbonate fuel cells

Fuel cells are best suited for the growing DG market. First of all, they are clean. Engines and turbines will never achieve the environmental friendliness needed by the market place. Environmental acceptance, which started in California, is spreading throughout the US market, indeed the world. Secondly, engines and turbines will never achieve the efficiency of fuel cells for small capacities less than 20 MW in size. This is especially true as turbine size decreases and the relative clearance, and hence the relative gas slippage, between case and blade tip increases.

Molten carbonate fuel cells (MCFCs) are the most efficient type of fuel cell (see Fig. 1). MCFCs are 50 to 100% more efficient than turbines in this size range. All the efficiency improvements now being promised for turbines (steam injection, combined cycle, thermochemical recuperation, etc.) apply to large turbine systems of 50-200 MW where economies of scale apply. Such improvements are not economical for small turbine generators, which are only 25-35% efficient. Therefore, turbines will not compete with fuel cells for applications below 20 MW, each has its own market

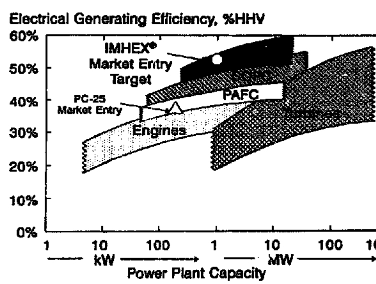

Fig. 1. Performance comparison. MCFC: molten carbonate fuel cell, SOFC: solid oxide fuel cell, and PAFC: phosphoric acid fuel cell.

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niche. It is a misconception to consider turbines and MCFCs as competitive technologies in this size range.

3. M–C Power corporation

M–C Power was formed in 1987 with one single mission: to develop and commercialize the IMHEX® molten carbonate fuel cell (MCFC) concept and capture a share of the growing DG market with a cleaner, more efficient product. M–C Power occupies three buildings in Burr Ridge, IL, a suburb of Chicago. M–C Power and its development team partners (The Institute of Gas Technology, Bechtel Corporation, and Stewart and Stevenson Services Company) employ more than 100 technical staff totally dedicated to the development of IMHEX®.

M–C Power's factory includes two 48-inch tape casting machines for making active components, e.g. anodes, cathodes and electrolytes. Tape casting allows the fabrication of very flat components with tolerances of less than 1 mil in thickness. Precision is the key to the assembly of high performance stacks. This factory also includes a controlled atmosphere furnace for sintering anodes and cathodes and a semi-automatic stack assembly machine for building stacks containing up to 350 cells: our 500 kW power module planned for market entry. We also have an automated 20 kW pilot stand for testing full-size advanced components.

Our factory is totally dedicated to stack development and manufacturing. IGT, the inventor of the IMHEX® concept, is responsible for advanced component technology. Bechtel Corporation, one of the world's largest engineering and construction firms, is responsible for power system design. Stewart and Stevenson, the world's leading producer of skid mounted power plants, is responsible for power plant assembly, marketing, sales, and service. We assembled this team to cover the entire range of commercialization activities; from development, through market entry, to full-scale production.

4. Commercial development

Our commercialization program is divided into two phases. Phase I concludes with the design, construction, and operation of two 250 kW demonstration plants: one at Unocal and one at San Diego Gas and Electric Company (SDG&E). Phase II culminates in the design, construction, and operation of a 1 MW commercial prototype which is scheduled for operation in 1998 (see Fig. 2).

The first 250 kW demonstration plant at Unocal was completed earlier this year. This plant included our first 250-cell stack which was completed, preconditioned, and proofed at M–C Power prior to shipment to Unocal. The stack performed well at M–C Power, producing 80 kW of electricity, the limit of our facility. However, after several start-up attempts at Unocal, the test was aborted due to poor performance, and the stack was returned to M–C Power for analysis. Although the stack performed poorly, a great deal of system design, fabrication, siting, and operating lessons were learned at Unocal. Most of the balance-of-plant (BOP) components operated well and stack assembly, preconditioning, and proofing at M–C Power was quite successful.

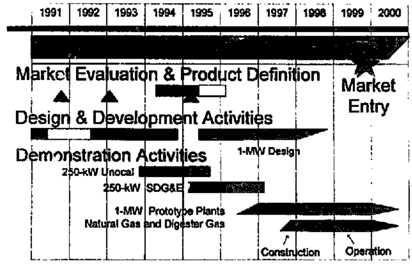

Fig. 2. Commercialization schedule.

These lessons are now being incorporated into the design of the SDG&E demonstration plant, which is scheduled for start-up in early 1996. A new flat plate reformer, designed and built by Ishikawajima–Harima Industries (IHI), will be used at the SDG&E site at Miramar. The IHI reformer has been factory-tested and is now being shipped to Miramar. The BOP skid for this plant is now being fabricated at Stewart and Stevenson. This skid will be shipped to Miramar later this year.

5. Market-entry power plant

Bechtel Corporation has completed an initial design of our 1 MW market-entry power plant. This plant will achieve 80% efficiency, 60% as electricity and 20% as high quality byproduct heat. The design closely integrates the stack and reformer; both will be housed in the same vessel to minimize piping runs and optimize heat integration. Bechtel Corporation estimates the capital cost of this plant at US $1200–1600 per kW, depending on production volume and power output. Cost breakdown is about 1/3 stack and 2/3 BOP (see Fig. 3).

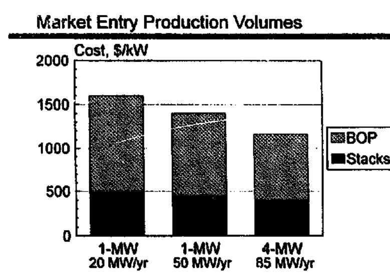

Fig. 3. Power plant cost estimates.

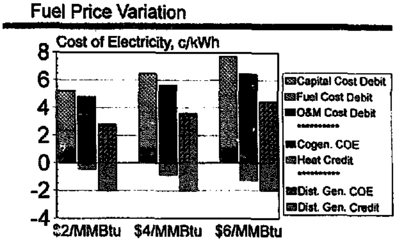

Fig. 4. Cost-effective electricity.

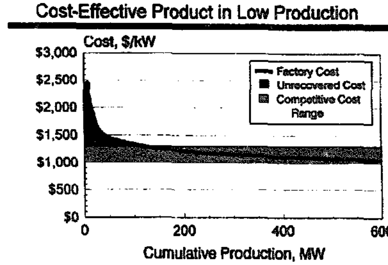

Fig. 5. Product strategy.

This capital cost will result in a competitive COE. Capital cost is not the only factor affecting the COE, being not the major factor. Fig. 4 shows the effect of several other factors for a 1 MW plant costing US $1500 per kW. The COE ranges from:

1. 5–8¢/kWh for electric only production;
2. 4–6¢/kWh for cogeneration, and
3. 3–4¢/kWh for distributed generation.

COE depends on the cost of natural gas, the value of by-product heat, and the credits taken for distributed generation. These COEs are very competitive, especially for DG, even at the relatively higher capital cost for small MCFC power plants.

6. Market-entry strategy

Stewart and Stevenson is now beginning a novel trade-in strategy for product introduction. This approach allows current buyers of conventional generators, such as diesel engines, the option to trade their engine for an IMHEX® fuel cell when it becomes commercially available. This strategy will allow IMHEX® to penetrate an already-existing customer market, which will significantly smooth the transition from development to full-scale commercial production. This transition period usually results in the so-called 'cost/price gap' because prices cannot support the high cost of low production. This is an especially large challenge for small companies, such as M–C Power.

Our analysis of this challenge is shown in Fig. 5, which indicates the difference between the cost and price of IMHEX® plants during the critical transition period. This cost/price gap amounts to about US $25 million over a 3-year market-entry period. This is a sizeable, but not insurmountable, amount of capital for a small company to raise. However, it is much less than the US $100–200 million sometimes quoted by others as an insurmountable deterrent to the success of small fuel cell companies. Given a highly capable development team, a promising product, and a sound market-entry strategy, we see no difficulty in raising US $25 million to bridge this gap.

It is, however, essential that product development, and related cost reduction, continue throughout the market-entry period. Thus, product costs and the time to reach cost/price parity are significantly reduced, as are the capital funds needed to bridge the cost/price gap. In other words, cost reduction is principally effected by improving the product, not by relying on increased production alone, the usual approach considered for most manufactured goods.

The IMHEX® team has all the necessary ingredients to effect this strategy. IGT and M–C Power will work on stack improvements, Bechtel Corporation will work on system improvements, and Stewart and Stevenson will develop the market using their novel trade-in approach.

7. Conclusions

Our team sees many applications for IMHEX®, in addition to DG. These include pipeline compressor stations, commercial buildings, and industrial sites in the near term and repowering applications in the longer term. In summary, Bechtel Corporation has designed our initial market-entry unit which we can now use to conduct trade-off optimization studies that will be used to guide our development program. IGT continues to improve our component technology, M–C Power will continue to reduce stack costs, and Stewart and Stevenson will expand their marketing activities.