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Utility experience with a 250-kW molten carbonate fuel cell cogeneration power plant at NAS Miramar, San Diego

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Abstract

This paper focuses on the strategy and experience of San Diego Gas and Electric with the development and demonstration of a proof of concept 250-kW internally manifolded heat exchanger (IMHEX®) carbonate fuel cell power plant. The plant was installed, commissioned, and operated by San Diego Gas and Electric (SDG&E) in a cogeneration mode at the Naval Air Station (NAS) at Miramar in San Diego. These activities were part of a collaborative effort between SDG&E and M-C Power's Program team (IMHEX® Team). The IMHEX® Team consists of M-C Power, Bechtel Engineering, Stewart and Stevenson, and the Institute of Gas Technology (IGT). The technical aspects of the plant's commissioning and operation were addressed by my colleague, J. Otahal, in a poster presentation. Our activities in carbonate fuel cell development are unique because of the level of involvement by an investor-owned utility in the development, engineering, installation, operation and maintenance of a fuel cell demonstration plant. The following topics are discussed in this paper: (i) SDG&E's involvement in the development of molten carbonate fuel cell (MCFC) technology; (ii) the active role in engineering and specification of the IMHEX® MCFC demonstration plant; (iii) responsibility for installation, commissioning, and operation; (iv) utility role in technology development and application of MCFC in a restructured and competitive environment; (v) summary. Published by Elsevier Science S.A.

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1. Introduction

Traditionally, technology development is performed by industry, primarily to develop new products or improve existing products to support the core business of an organization and establish a competitive edge. At SDG&E, like many investor-owned utilities in the USA, technology development activities are traditionally performed primarily for the benefit of ratepayers. The focus of utility technology development is typically to improve performance of generation, transmission and distribution assets, and to mitigate environmental issues. This concept of technology development in utilities, however, is changing due to the pending utility restructure in the USA.

Nearly a decade ago, the US electric industry was deluged with an over-capacity of generation resources and SDG&E anticipated no new large central power plant construction in California. From a strategic perspective, SDG&E development activities focused on identifying alternative solutions, such as distributed generation (DG), to potentially meet future local load growth. Fuel cells were an option within our technology development portfolio of DG technologies.

2. Strategic perspective

Our perspective of DG around 1989 was that it would take nearly a decade more for DG applications to enter the market place. Our technology development strategy, therefore, was to assist the development of technology targeted to be in the market place by 2000. Also, in view of the political and economic climate in California, DG technologies would have superior efficiency and be environmentally acceptable.

Consequently, a program was initiated within SDG&E's product development group to focus on future generation technology that would meet environmental and economic targets. Fuel cells quickly rose to the top of the list of candidate technologies. Based on a due diligence in fuel cell

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technology, carbonate fuel cells were identified as a resource that could be deployed as a DG and potentially as a repowering option of existing central generation assets.

Anticipating the availability of a commercial fuel cell products in 1999-2000, we established a development program in molten carbonate fuel cell (MCFC) technology with M-C Power Corporation.

3. Development program

Considerations for a technology development program with M-C Power encompassed a review of their business plan, which included their business strategy, commercialization program, program team (IMHEX® Team), product design, and business options for SDG&E with commercial MCFC products.

Our review concluded that M-C Power's plan for meeting target costs was prudent and their targeted market was consistent with our strategy. There were no exotic materials used in the technology, plans for meeting target costs were fast paced, and we saw no major technological breakthroughs required for the commercialization of IMHEX® fuel cell technology.

Elements of our relationship with M-C Power included development activities of cell components, endurance testing of a 20-cell 1000 cm^2 stack for 7100 h, pressurized test modules, product development assessment, and the demonstration of a 250-kW proof- of-concept plant.

By 1993, however, the interest at SDG&E in long-term technology development began to fade because of the initial efforts in California to restructure electric utilities. SDG&E's long-term product development efforts were shifted to activities that would be commercial in 3-5 years. Technology development programs such as fuel cells, had to be restructured to deliver economic or customer satisfaction benefits to SDG&E beyond those originally envisioned.

4. Value from development activities

In 1993, SDG&E implemented the first performance based rate-making (PBR) process approved by the California Public Utility Commission. The measurements for PBR included a component for customer satisfaction and improved system performance as benefits.

The US Navy, the largest SDG&E customer, welcomed the opportunity to participate with SDG&E in the demonstration of MCFC technology in their facility, the Naval Air Station (NAS) at Miramar. The value to the Navy, in demonstrating MCFC technology, was the energy to be delivered to the base and gaining experience with a new generation technology.

By selecting a key customer, such as the US Navy, as the host site for the fuel cell demonstration plant, the value of continuing our development activities with M-C Power became one of improved customer satisfaction, which contributed towards meeting our PBR goals. Additional value to SDG&E was established by including EPRI's participation in the development of the IMHEX® technology and establishing a utility consortium in support of the fuel cell demonstration plant at NAS Miramar.

5. Participants in the demonstration project at NAS Miramar

Completing the 250-kW MCFC demonstration plant at Miramar was by no means a trivial effort. M-C Power lead this effort under the guidance of Joseph Scroppo, project manager of their Product Development Program with the US Department of Energy (DOE). Mr. Scroppo's responsibility included the coordination of all facets of the project with the IMHEX® Team and SDG&E as the host utility.

Bechtel Engineering was responsible for plant design and the specification and procurement of large equipment, Stewart and Stevenson was responsible for procurement of small equipment and packaging the balance of plant components. SDG&E was responsible for host site selection and permitting. M-C Power was responsible for the fabrication of the fuel cell stack. Ishikawajima Harima Heavy Industries (IHI) supplied the flat plate fuel reformer.

SDG&E participated with the IMHEX® Team to provide a utility's perspective to the engineering and control design process of the demonstration MCFC plant. In addition, SDG&E assumed responsibility for plant installation, commissioning and operation. The SDG&E project team responsible for installation commissioning and operation included plant engineering, product development, maintenance and operations, electrical construction and construction management.

The uniqueness of this project are many-fold including the first 250-kW flat plate reformer, the first 250-cell carbonate fuel cell stack (area 1 m^2) in a thermally integrated design, complete electronic control of the entire plant, relatively short plant start-up period, and utilizing SDG&E's project management, engineering, and technical support groups.

6. Experience with demonstration plant

The overall experience with the demonstration MCFC plant in San Diego was very positive. Representatives from the IMHEX® Team and the SDG&E team, from engineering to operation and maintenance, worked well together and were mutually supportive and very involved from installation to commissioning and operation. Without all the participant's support and enthusiasm, the success of this project would not have been achieved.

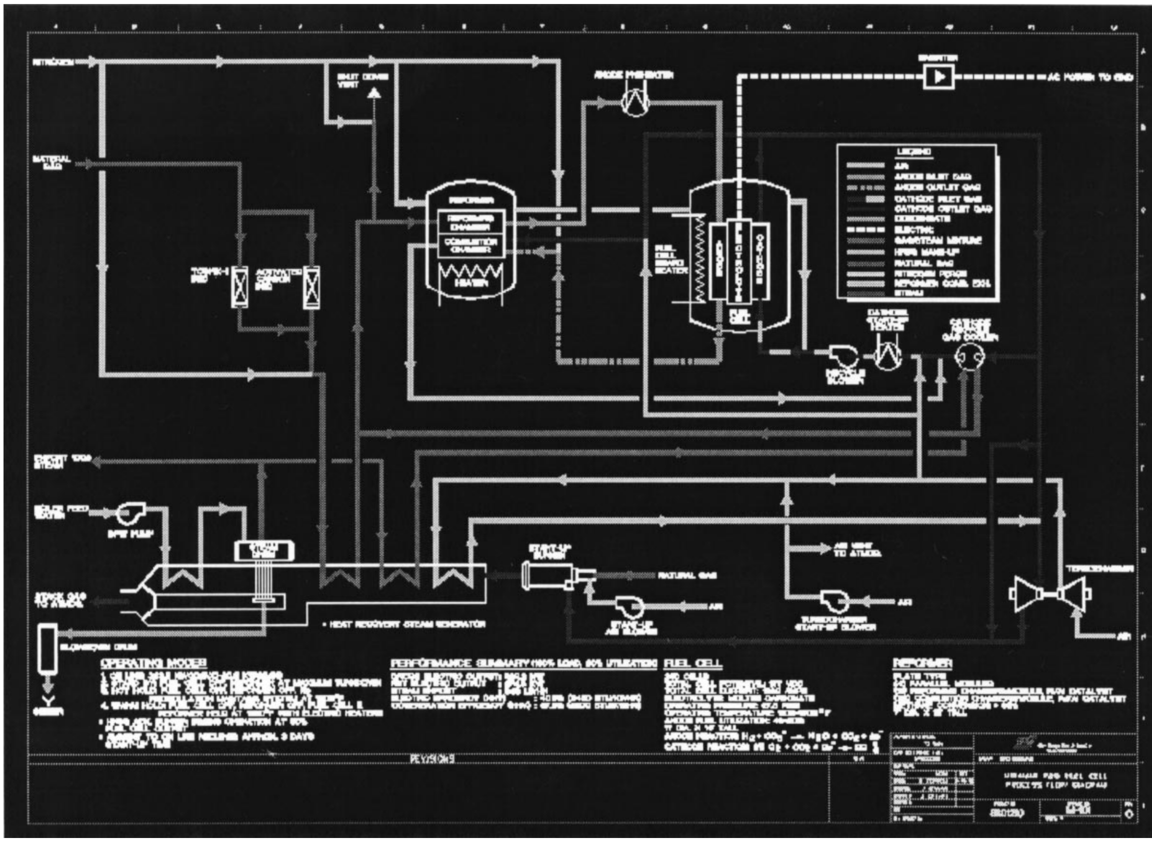

Fig. 1. 250-kW MCFC process diagram.

In the process flow diagram shown in Fig. 1, you can see that there are only five rotating pieces of equipment. Two of these pumps are blowers used during the start-up service. The cathode recycle blower, turboexpander, and boiler feed pump are the only rotating process equipment in operation during load condition. Initial start-up of the fuel cell, reformer, and heat exchanger and steam generator (HRSG) proved to be trouble free. In contrast, the control system, certain rotating equipment, and the inverter were problematic and required creative intervention to establish the plant as an operating system.

During the phase I test, the demonstration plant operated for nearly 3000 h, from January through June 1997, delivering a total of about 160 MWh of electricity and 346 000 pounds of steam to the Navy's grid. The maximum power output was 210 kW and Fig. 2 shows the power output over the period of operation. The reason for the reduced power output from the plant, was due to a high pressure drop across the cathode in the stack. The stack however, performed relatively well, delivering nearly 80% of the anticipated power density of 110 W/ft^2. The resident plant crew during operation consisted of five operators, a plant engineer, and two part-time maintenance persons. The plant was manned by a single operator 24 h a day.

Currently, the plant is on a standby mode awaiting system modifications based on the lessons learned from the phase I test. Plant modifications will include a modified turboexpander, a new hot gas blower, and some piping rework. During the standby period of time, we have reduced the plant personnel to a crew of two operators and a part-time plant engineer to reduce expenses. We anticipate beginning plant modifications in October 1997 and restarting the plant in February 1998 for additional component and system performance verification.

7. Scenario for DG and MCFC in a restructured utility environment

Utility restructure in California is still in flux. Many issues remain to be settled including whether or not distribution utilities can own DG technology or simply purchase the service from a third party. The value of DG to an electric distribution utility is still uncertain because of the complexity in operating a distribution system. Also, it is uncertain as to how long a DG application may be used as a substitute for distribution system upgrades.

We anticipate that in a competitive utility environment, the type of generation technology to be used for DG applications will be evaluated for the overall value it delivers to the customer beyond the conventional economic factors of capital, operation, and maintenance cost. How is this related to fuel cell technology? The application of fuel cell technology as a DG resource will depend on economic factors.

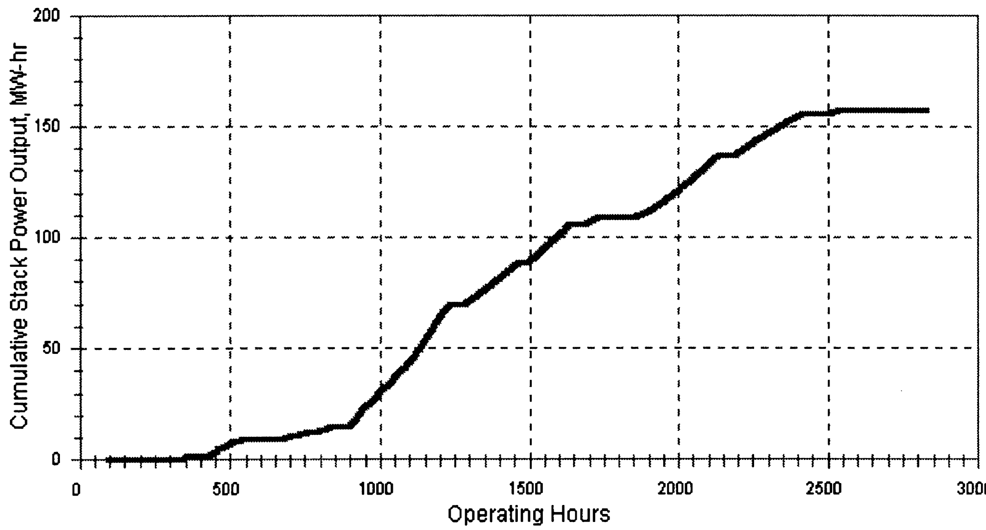

Fig. 2. 250-kW IMHEX cumulative DC power plant output history at Miramar.

However, criteria such as the political climate, environmental limits, permitting, and system efficiency may be key factors in the selection of generation technology for DG applications. We anticipate that environmentally acceptable technology such as fuel cells may play a significant role in meeting DG needs.

The market for fuel cells, however, is still undefined because of the perception that even the fuel cell technology closest to commercialization, the phosphoric acid fuel cell, is still in the development stage due to its high capital cost. In order for fuel cells to compete in the restructured energy market, suppliers need to implement significant efforts to reduce the cost of installed plants and demonstrate superior system performance, product endurance, and overall system reliability.

These are costly development and demonstration programs that no supplier alone would be able to support. To attract government funding for a robust fuel cell development program that would lead to a successful commercialization program of MCFC, the electric power provider industry must show interest in the technology, ergo establishing the potential market for fuel cells. A joint effort between the power provider industry, fuel cell suppliers, related industry and government, would facilitate the commercialization of fuel cell technology in the 2005 timeframe. Lacking the market pull with support from industry and government, commercialization of MCFC is likely to be delayed. The reason is that in a competitive energy market, the electric power provider industry will be focused on short-term financial results to the detriment of long-term customer needs.

8. Summary

Utility involvement in long-term development and demonstration programs are giving way to short-term programs that meet near-term competitive needs. Development programs such as ours at Miramar, play a vital role in stimulating technical innovations required to truly commercialize fuel cell technology. But, as the utility business changes to a more competitive environment, these type of programs will be less likely to materialize unless robust joint industry and government efforts are established.

Although our overall experience with the demonstration fuel cell plant at NAS Miramar has been very positive, utility support of long-term technology development activities will most likely not continue. In a restructured utility environment, technology development efforts, by utilities, will most likely be focused primarily on distribution operation activities and be short-term (18-24 months).

During our demonstration project at Miramar, we identified essential areas of fuel cell stack and balance of plant (BOP) improvements. The problems we encountered with BOP equipment were not insurmountable, however, there was a performance deficiency in some 'off-the shelf components'. This indicates that development work is needed in BOP equipment for carbonate fuel cell plant technology and a joint industry program may be appropriate in this area to leverage limited R and D funds.

In a utility restructured environment, business decisions will override technology issues that are not of immediate concern unless they yield high returns. The market and value for DG applications are not yet well defined, but we anticipate that conventional technology would be preferred, in the short-term, to technology in the developmental stage because of familiarity and first cost. The commercialization of fuel cells in power generation applications will come only as a result of successful collaborative development efforts between industry and government to ensure that cost goals are met and confidence in the technology increases.

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