Santa Clara Demonstration Status

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Introduction

Fuel Cell Engineering Corporation (FCE) is in the fourth year of a DOE Cooperative Agreement Program (private-sector cost-shared) aimed at the demonstration of ERC's direct carbonate fuel cell (DFC) technology at full scale. FCE is a wholly owned subsidiary of Energy Research Corporation (ERC), which has been pursuing the development of the DFC for commercialization near the end of this decade. The DFC produces power directly from hydrocarbon fuels electrochemically, without the need for external reforming or intermediate mechanical conversion steps. As a result, the DFC has the potential to achieve very high efficiency with very low levels of environmental emissions. Modular DFC power plants, which can be shop-fabricated and sited near the user, are ideally suited for distributed generation, cogeneration, industrial, and defense applications. This project is an integral part of the ERC effort to commercialize the technology to serve these applications.

Objectives and Approach

Potential users of the commercial DFC power plant under development at ERC will require that the technology be demonstrated at or near the full scale of the commercial products. The objective of the Santa Clara Demonstration Project (SCDP) is to provide the first such demonstration of the technology. The approach ERC has taken in the commercialization of the DFC is described in detail elsewhere [1]. Briefly, an aggressive core technology development program is in place which is focused by ongoing contact with customers and vendors to optimize the design of the commercial power plant. ERC has selected a 2.85 MW power plant unit for initial market entry. Two ERC subsidiaries are supporting the commercialization effort: The Fuel Cell Manufacturing Corporation (FCMC) and the Fuel Cell Engineering Corporation (FCE).

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FCMC manufactures carbonate stacks and multi-stack modules, currently from its manufacturing facility in Torrington, CT. FCE is responsible for power plant design, integration of all subsystems, sales/marketing, and client services. The commercial product specifications have been developed by working closely with the Fuel Cell Commercialization Group (FCCG). FCCG members include municipal utilities, rural electric co-ops, and investor owned utilities who have expressed interest in being the initial purchasers of the first commercial DFC power plants. The utility participants in the SCDP have been drawn from the membership of FCCG.

FCE is serving as the prime contractor for the design, construction, and testing of the SCDP Plant, and FCMC has manufactured the multi-stack submodules used in the DC power section of the plant. Fluor Daniel Inc. (FDI) served as the architect-engineer for the design and construction of the plant, and also provided support to the design of the multi-stack submodules. FDI is also assisting the ERC companies in commercial power plant design.

Project Description

The project involves the design, construction, and testing of a 2MW DFC demonstration power plant in the city of Santa Clara, California. The site for the plant is located at 1255 Space Park Drive in Santa Clara. The site is owned by the City's Electric Department and is immediately adjacent to the Scott Receiving Station, a 115/60kV switching station on the City electrical system. The plant occupies a portion of the site, measuring approximately 150 by 150 feet. The power plant layout is illustrated in Figure 1.

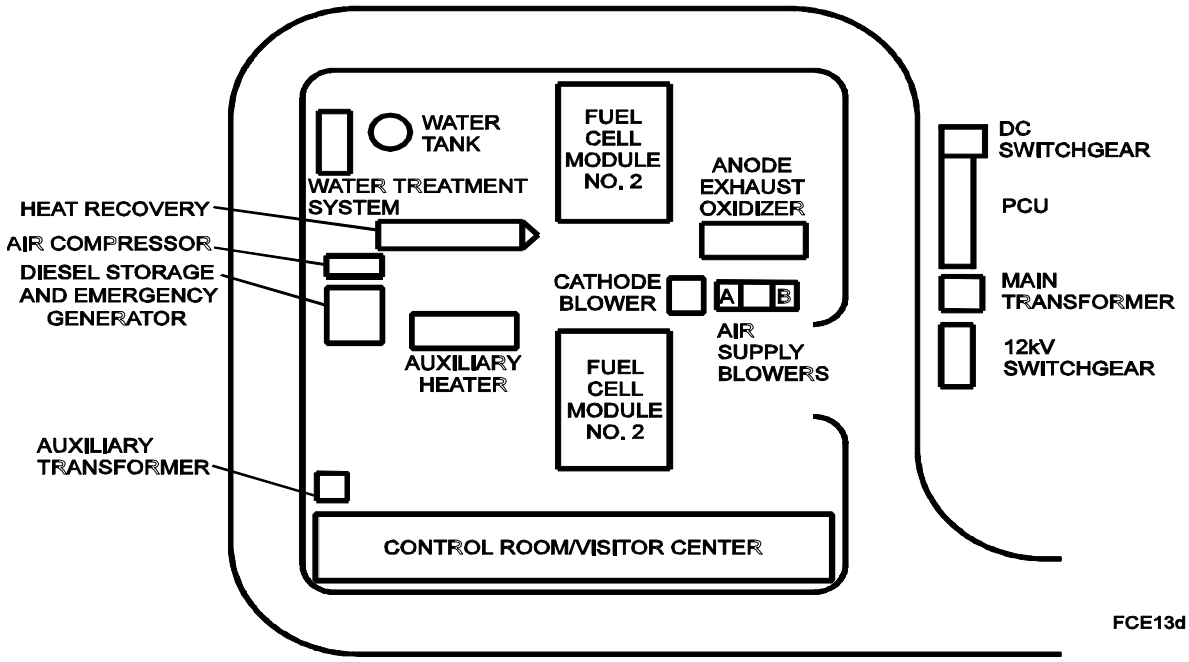

FIGURE 1
Santa Clara Demonstration Plant Layout

The power plant uses 16 fuel cell stacks, each rated at 125kW. The stacks have been fabricated by ERC's manufacturing subsidiary, Fuel Cell Manufacturing Corporation (FCMC). The stacks were fabricated and assembled into four 4-stack submodules in FCMC's Torrington facility and truck shipped to the Santa Clara site, where they were installed into the two 1MW modules which comprise the DC power section of the plant. The key plant design specifications are listed in Table 1.

Table 1
SCDP Design and Performance Criteria
The Performance Targets are Based on Commercialization Objectives

Nominal Capacity	2 MW
Plant Rating, net AC	1.8 MW
Heat Rate (LHV) at Rated Power	6850 Btu/kWh
Maximum Emissions at Plant Rating SO_x NO_x CO_2	 0.003 lb/MWh 0.0004 lb/MWh 845 lb/MWh
Noise	60 dB(A) at 100 ft
Availability	90%
Startup Time, Cold Start to Rated Power	40 hours
Ramp Time, Standby to Rated Power	30 minutes
Reactive Power	+/- 1.67 MVAR

Results

Construction of the balance of plant (the power plant systems not including the fuel cell submodules) was completed in June 1995. In place of the fuel cell submodules, spool pieces had been installed connecting fuel cell inlet and exit lines. This allowed the system to be tested without the fuel cell stacks in a series of BOP pre-test activities. The BOP pre-test effort identified and corrected a number of BOP problems, and the required modifications were made to resolve all issues by the end of the pre-test period.

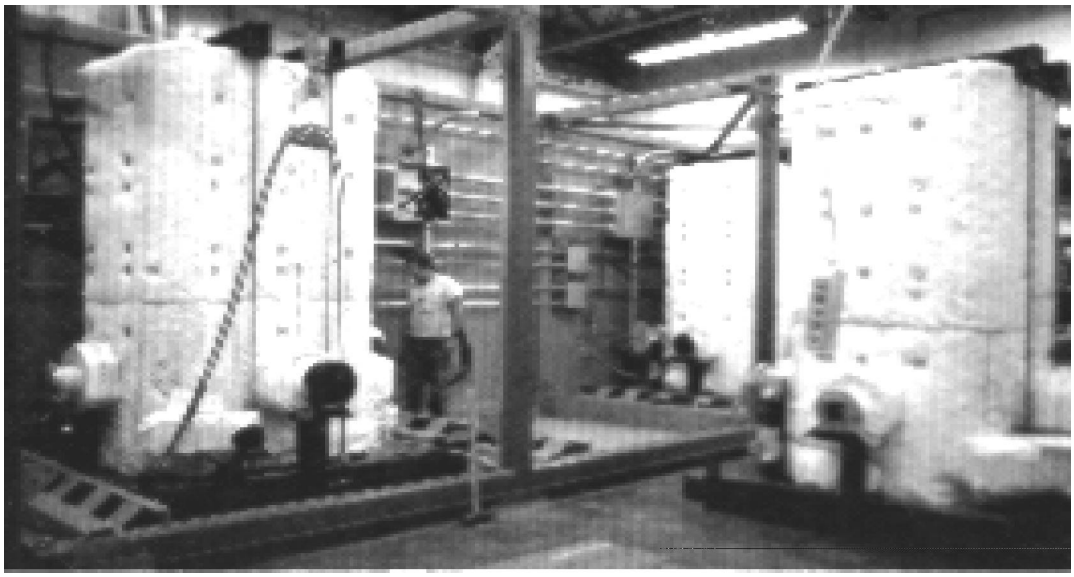

FIGURE 2
Stack Submodule Production Activities at Fuel Cell Manufacturing Corporation
The Completed Submodules Included the Fuel Cell Stacks and Related Mechanical, Electrical and Instrumental Connections

FIGURE 3
Four-Stack DFC Fuel Cell Submodule In Transit to SCDP Site
The Submodules Were Shipped Across the Country From Torrington, CT to Santa Clara, CA

While fabrication of components for the fuel cell stacks had been initiated in earlier reporting periods, most of the final stack assembly effort was done in calendar year 1995. As fabrication of four-stack groups was completed, the stacks were installed into submodule enclosures. Figure 2 shows stack submodule fabrication activities at FCMC. The figure shows one of the submodules with one stack installed, a second being rigged into place, and a third waiting to be placed in the submodule. Each submodule consists of a sealed enclosure which includes gas connection piping, instrumentation, and electrical connections. The completed submodules were sealed and truck shipped to the SCDP site. Figure 3 shows one of the units being shipped to the site.

The submodules arrived at the site over the period of November 1995 through February 1996. As the units were delivered they were stored in a laydown area adjacent to the power plant. Once all four units had been delivered, and the BOP pre-test effort had been successfully concluded, the four submodules were installed in the plant. Figure 4 shows the completed power plant after the stack submodule installation.

The power plant acceptance test period has been initiated, beginning with the initial plant start-up, which includes some catalyst, matrix, and electrode conditioning steps which are unique to the first plant heatup. The initial startup demonstrated that the conditioning operations can be controlled sufficiently to allow the start-up of multiple-stack systems. The initial open circuit voltages for the sixteen stacks were equal to within 0.5%, with stack voltages of 251 +/-1 Volt. The successful conditioning of these 16 stacks simultaneously was a significant project milestone.

FIGURE 4
Santa Clara Demonstration Plant After Completion of Construction
The Test Program Has Begun and the Plant Has Produced its Rated Power Output

The initial power ramp was begun after the conditioning process was complete. The power plant has been operated at its 1.8 MW net AC rated power level, and at power levels as high as 1.93 MW net AC (2.17 MW DC), making it the largest fuel cell power plant ever operated in the U.S. Operating efficiency in this early phase of operation has been as high as 44% LHV.

Beginning approximately 520 hours into the plant operation, intermittent anomalies were observed in some of the stack voltages. In order to determine the cause of these events, the power plant was shut down and cooled to ambient temperature for inspection. The cause was determined to be parasitic electrical circuits, caused by a breach of the electrical isolation between the fuel cell stacks and the gas distribution piping. The source of these circuits was traced to a construction aid material used to install the thermal insulation around the fuel cell stacks. At elevated temperatures the construction aid material became electrically conductive, diminishing the effectiveness of dielectrics used to isolate fuel and air metal pipes from the fuel cells. Since differential potentials can reach 1000 VDC in the power plant, it became possible for stray parasitic currents to flow through the tainted dielectrics.

FCE has completed the process of removing the causative construction aid material and cleaning or replacing the damaged dielectric piping. As of the writing of this paper, the power plant restart has been initiated.

Future Activities

Having completed the repair effort on the submodule electrical isolation, the acceptance test effort will now resume. The acceptance test includes a total of 1000 hours system operation, during which time the plant performance is measured against the design criteria described above. Following the completion of the acceptance test, an additional 9000 hours of endurance testing is planned.

The SCDP project has already begun to meet its objectives. The work to date has demonstrated that a megawatt scale DFC plant can be configured using truck-shipped multi-stack submodules, and that a multiple stack system can be started and operated with excellent performance and uniformity among the stacks. The power plant has already met its rated power design criteria, and demonstration of the remaining criteria is planned as the testing is continued.

Acknowledgements

The design and fabrication of the fuel cell stack modules was done with U.S. Department of Energy support through METC, under Cooperative Agreement DE-FC21-92MC29237. The

guidance and support of the METC Contracting Officer's Representative, Mr. Thomas J. George, has been greatly appreciated. The period of performance for the Cooperative Agreement is October 1, 1992 through September 30, 1997.

The design and procurement of the balance of plant and the construction and testing of the complete system has been supported by the Santa Clara Demonstration Participants. The participants in the SCDP are as follows: City of Santa Clara, City of Los Angeles Department of Water and Power, City of Vernon, Electric Power Research Institute, National Rural Electric Cooperative Association, Sacramento Municipal Utility District, and Southern California Edison Company. Salt River Project (SRP) and the Northern California Power Agency (NCPA) are also supplying some project funding through a consortium agreement with the City of Santa Clara. The guidance and support of the SCDP project manager, Mr. Thomas P. O'Shea has been greatly appreciated.

EPRI has also provided funding beyond its SCDP participant share, to support early design and optimization efforts in the project. ERC/FCE is also contributing funding to the project. In addition, the California Energy Commission has provided funding to the City of Santa Clara to support the balance of plant pre-test activities.

References

[1] H. Maru, et al.; ERC Program Overview. *Proceedings of the Fuel Cells '96 Review Meeting. August 1966*

[2] Leo, A.J., et al.; Development and Demonstration of Direct Carbonate Fuel Cell Systems at Energy Research Corporation. *Proceedings of the 31st IECEC Conference, Washington, DC. August, 1996*

[3] Leo, A.J., et al.; Status of Santa Clara MCFC Product Development Test. *Proceedings of the Fuel Cells '95 Review Meeting, August 1995*. p 165. DOE/METC-95/1020. NTIS DE96000554.