II.F.3 Alkaline, High-Pressure Electrolysis

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Objectives

Develop and construct an alkaline hydrogen generator to meet the following objectives:

- Higher overall efficiency
- Low maintenance cost
- DFMA (Design for Manufacture and Assembly)
- Final output pressure of 5000 psig

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- Q. Costs
- R. System Efficiency
- T. Renewable Integration

Approach

- Perform trade studies and analyses to optimize system characteristics.
- Design the cell.
- Design the module.
- Design support system.
- Fine-tune design and controls.
- Design for manufacture and assembly.
- Fabricate deliverable system.

Accomplishments

- System efficiency and tradeoff studies in progress.
- Cell design in progress. Initial efforts will allow reduction in number of parts in a cell assembly by up to 40%.
- Module design in progress. Currently performing structural modeling using finite element analysis (FEA) software.
- Membrane development hardware on order. This will allow for uniformity of the membranes that Teledyne Energy Systems Inc. (TESI) fabricates for this project.

Future Directions

- Optimize system operating pressure with respect to cost and efficiency.
- Complete design of electrolysis module.
- Test improved fabrication procedure.
- Fabricate benchtop system(s).
- Test and optimize benchtop system(s).
- Conduct DFMA engineering.
- Design and fabricate deliverable system.
- Finalize and arrange a demonstration site.

Introduction

This project will contribute to the enabling and acceptance of technologies where hydrogen is the energy carrier between renewable energy resources and clean energy consumers. There are many opportunities for expanding from traditional industrial applications to transportation and stationary use in a more common setting. The lowering of capital costs driven by DFMA efforts and lowering of operating costs resulting from efficiency improvements will make electrolysis systems more feasible for early adopters and will help USA manufacturers maintain a competitive position in traditional and future markets.

Specific goals of the project involve moving towards DOE's technical targets as outlined in the hydrogen production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan. This includes aggressive improvements in cost, efficiency, operation and maintenance of the electrolysis system.

Approach

The main objective of this project is to design, manufacture, test and demonstrate a low-cost, high-pressure electrolysis system capable of delivering 99.99% pure hydrogen to a vehicle refueling interface. The electrical power management will be flexible to allow demonstration with standard AC grid power or with a renewable energy source. The proposed system will have a capacity of 10,000 scfd. The project will place critical emphasis on design for manufacture and assembly (DFMA) and on developing a production strategy to achieve this rate of production.

In the final phase of the project, the deliverable system will be installed in a high-quality, transportable industrial building and final acceptance tested. The scope of work includes liaison activities, commissioning and training to support one demonstration for 6 months, probably in the State of Maryland, but intended to be accessible from the nation's capital.

A substantial effort in the proposed scope of work is focused on manufacturing technology, collecting and analyzing cost data, designing and optimizing production processes, and performing a financial analysis of the production line and its facility. The demonstration system will include only those features and components which meet the per-unit cost objective when high quantities are assumed.

Ongoing key elements of this project include safety, reliability, and quality engineering. These will assure a safe system design at higher pressures, a reliability program and quality control aspects to address both the demonstration unit build as well as the quality engineering, material controls and automation needed for a large production operation. The safety efforts will include application of traditionally applied codes for flammable and compressed gases, as well as new codes and standards being developed for renewable energy situations. Teledyne will participate in liaison activities pertaining to public safety, including training, public education and assistance in obtaining regulatory permits for the system demonstration.

The generator design will build on TESI's 30+ years commercial product experience base with improvements in conversion efficiency and a design to reach an electrolysis system operating pressure between 600 and 1,500 psig. A compressor based on mature technology will be used to reach the 5,000 psig final pressure. Activities with the compressor and power supply manufacturer will be focused on improved operating efficiency, a major cost reduction, a higher level of system integration, and inputs needed to support the manufacturing cost objectives.

Results

Awarded in March 2004, the project is nearing completion of its preliminary stages. Initial contact has been made with the key component suppliers and the demonstration site organization. Design work has been initiated and necessary hardware has been purchased.

Desktop Engineer stress and deflection software is being used to perform structural modeling and simulations for basic cell design. The results of these initial analyses are being applied to design and fabricate a high-pressure cell using alkaline resistant polymers. The final operating pressure of the cell is being determined. Initial studies estimate that the operating pressure will lie between 600 psig and 1500 psig for optimizing capital costs and operation efficiency in the system. Final compression to 5000 psig will be achieved by using a diaphragm compressor.

An important step in the design of this electrolyzer for manufacture and assembly of 10,000 units per year is reducing the number of parts in the system and the module and simplifying its assembly, as compared to commercially available electrolyzers. TESI's approach to reducing module components is to utilize integrated molding techniques for fabrication of the module cell components.

TESI has purchased hardware needed to consistently fabricate electrolysis membranes, which will improve the acceptance rate and reduce waste as compared to laboratory techniques. This is a significant step in taking electrolyzer fabrication from the laboratory to a manufacturing environment.

Conclusions

A new electrolyzer module is being developed at TESI to support DFMA heuristics and operate at a pressure between 600 and 1500 psig. This module will be integrated into a high-efficiency system with a final hydrogen output pressure of 5000 psig.

Future work will include testing the newly designed cell and module along with the newly developed fabrication techniques. Benchtop systems may be constructed to study module lifetime and validate control techniques and strategies. Hazards and Operational Safety Analysis/Failure Modes and Effects Analysis (HAZOP/FMEA) studies will be performed and used to drive any safety-related engineering. TESI will then design and fabricate the deliverable system, which will include consolidation of sensors and controls between its various components along with engineering considerations to minimize the capital, operational and maintenance costs.

FY 2004 Publications/Presentations

1. S. Cohen and S. Ibrahim, "Hydrogen Generation from Electrolysis," 2004 DOE Program Review Presentation, Philadelphia, PA (2004).