II.F.2 Renewable Electrolysis Integrated System Development and Testing

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Objectives

- Examine the issues with using renewable energy to produce hydrogen by electrolyzing water.
- Characterize electrolyzer performance under variable input power conditions.
- Test and evaluate the electrical interface with renewable (photovoltaics, wind, hydro, geothermal, etc.) and/or hybrid/grid power for:
  - Dedicated hydrogen production
  - Electricity/hydrogen cogeneration
- Design and develop shared power electronics packages and controllers to reduce cost and optimize system performance.
- Develop and verify integrated renewable electrolysis systems through performance modeling, simulation and testing.

Technical Barriers

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

- Q. Cost
- R. System Efficiency
- S. Grid Electricity Emissions
- T. Renewable Integration
- U. Electricity Costs

Approach

- Leverage the capabilities of the National Renewable Energy Laboratory's (NREL's) Distributed Energy Resources Test Facility and National Wind Technology Center to develop and test integrated renewable electrolysis systems.
- Conduct testing to determine impact of variable power inputs and load conditions on electrolyzer performance and lifetime.
- Develop an advanced power electronics interface that lowers renewable electrolysis system cost and improves system efficiency and performance.

Accomplishments

- Completed construction of the Hydrogen Electrolysis Test Facility (at the NREL National Wind Technology Center).
  - – Designed control, safety, and data acquisition systems.
  - – Interconnected facility to on-site renewable/distributed/grid power.
- Developed Renewable-Electrolyzer Test Plan for testing of 5-kW Proton Hogen 40 polymer electrolyte membrane (PEM) electrolyzer with 10-kW wind turbine and 10-kW photovoltaic (PV) array.
- Began characterization of electrolyzer under normal operation with utility grid and DC power in a variety of operating modes.

Future Directions

- Design and model the optimum power electronics interface to work with target wind turbines and electrolyzers.
- Determine the effect of intermittent operation on the efficiency and reliability of the various electrolyzer types.
- Design a multi-megawatt wind-electrolysis, electricity-hydrogen cogeneration system.
- Develop renewable power package designs for utility, residential, commercial, industrial and distributed generation markets.

Introduction

Renewable energy sources such as photovoltaics (PV), wind, biomass, hydro and geothermal can provide clean and sustainable electricity for our nation. Today, several of these options are already cost-competitive and are contributing nearly 10% of the U.S. electricity supply. However, one of the issues limiting greater penetration of these renewable energy sources is the fact that they have intermittent and seasonal availability for energy production. One solution to this problem is to produce hydrogen through the electrolysis of water and use that hydrogen in a fuel cell, either to fuel vehicles or to produce electricity during times of low power production or during peak demand (Figure 1). Currently, this approach is hindered by the ability to produce hydrogen from these renewable sources in a cost-competitive manner. In addition to the ongoing efforts to reduce the cost of renewable technologies and to lower the capital requirements for electrolyzers, optimization and tailoring of these renewable-electrolysis systems are needed to realize the most cost-competitive option for electricity and hydrogen production.

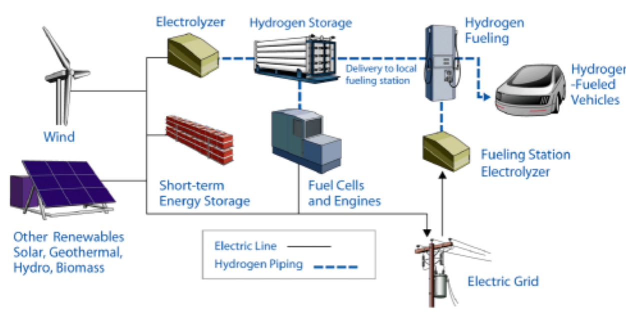

Figure 1. Schematic of Integrated Central and Distributed Hydrogen And Electricity Generation.

Most electrolyzers commercially available today are designed for grid-connected operation and, therefore, incorporate power electronics to convert AC from the grid to DC power required by the cell stack. These power converters can represent 25-30% of the total cost of the electrolyzer. Power converters are also required for the renewable energy source. For example, when using wind energy, variable-speed wind turbines rely on power electronics to convert the "wild AC" (variable frequency, variable voltage) produced at the generator to DC, which, when connected to the grid, must then be converted back to AC at grid frequency

(60 Hz). These power converters can also represent a significant percentage of wind turbine cost. Designing single power electronics packages and optimizing the sizing and integration of components are opportunities for improving the efficiency, cost and robustness of these systems.

Approach

Past research on integrating electrolyzers with renewables has focused on integrating commercially available electrolyzers and renewables, both complete with their own dedicated power electronics and controller. Our approach is to design a single power electronics package and controller that will eliminate this redundancy and allow matching of the renewable power output to the electrolyzer power requirements, leading to gains in system efficiency.

Electrolyzer performance is characterized based on varying input power under various load conditions. The experimental characterization results are combined with performance characteristics of a variable-speed wind turbine in order to design and model the optimal power electronics interface between the wind turbine and electrolyzer. By replacing the two separate power electronics interfaces with a single one that takes wild AC directly from the variable-speed wind turbine generator output and provides acceptable DC power to the electrolyzer, system cost will be reduced while increasing the robustness of the wind turbine-electrolyzer link. Furthermore, the single point of control will allow matching of the wind turbine and electrolyzer electrical characteristics, thereby increasing the energy capture of the wind turbine. Finally, this solution will eliminate the need for a constant-voltage DC bus and provide a true test of electrolyzer operation under fluctuating power input conditions.

Results

Construction of the Hydrogen Electrolysis Test Facility at the NREL National Wind Technology Center was completed. The facility is interconnected to the on-site renewable and distributed generation devices, including a 10-kW permanent magnet wind turbine and a 10-kW photovoltaic array. The 5-kW PEM electrolyzer has been installed (Figure 2). Sensors have been installed to monitor all gas and liquid flows, deionized water resistivity, system temperatures, and stack current and pressure. A data acquisition and control system was developed and installed to control the electrolyzer and facility safety systems.

Figure 2. Hydrogen Electrolysis Test Facility - 5 kW PEM Electrolyzer

Testing of the electrolyzer has begun, starting with the factory default mode, which utilizes AC utility grid power only for electrolysis and ancillary loads. Once operational readiness has been confirmed and shakedown of the sensors, safety system, and data acquisition and control system is complete, the following tests will be undertaken:

- DC power will be used for electrolysis and the AC grid will be used to supplement the DC power and supply the ancillary loads.
- DC power supplies will be programmed to simulate the output characteristics of the PV array based on current-voltage (I-V) curve information on the array and performance over typical solar days.
- The 10-kW PV array will be configured per the operating ranges of the DC interface of the electrolyzer.

Response of electrolyzer's DC controller to a variety of sine waves, ripple, and other harmonics will be determined. Performance of DC/DC power supplies under faster changing inputs will determine the amount of regulation required for PEM stacks.

Conclusions

Due to the relatively low cost of wind power, along with recent dramatic growth in wind energy, wind electrolysis is well poised to become the first economical renewable hydrogen production system. Before this can become a reality, though, cost and efficiency of commercial electrolysis systems must improve. Tradeoffs associated with hydrogen production rate, operational efficiency and capital cost must be optimized. Testing is needed to determine the effects of variable input power on the efficiency of electrolyzers, and research is needed to identify and demonstrate optimized integrated system configurations. Finally, the viability and durability of the integrated configurations must be validated under real-world operating conditions.

FY 2004 Publications/Presentations

1. Hock, S., C. Elam and D. Sandor, "Renewable Hydrogen: Can We Get There?" Solar Today, May/June 2004.

2. Sverdrup, G., C. Elam and M. Mann, "Hydrogen Production Technologies from Renewable Energy: A Status Report for the United States," Proceedings of the World Hydrogen Energy Conference, June 2004.