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INTEGRATED RENEWABLE HYDROGEN UTILITY SYSTEM

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Abstract

This paper describes the plans for a Phase II program recently awarded to Proton Energy Systems, Inc. (Proton) under cooperative agreement DE-FC36-98GO10341 with the Golden Field Office of the Department of Energy (DOE).

The ultimate goal of this project is to enable the link to sustainability by converting excess renewable power into hydrogen and having that hydrogen available for conversion back to power, on demand. Furthermore, the cost of this capability must be less than $1000 per kW and allow for a variety of renewable inputs.

Since the inception of the program on April 15, 1998, Proton has successfully demonstrated a fully functioning integrated renewable hydrogen utility system. The system, installed at Arizona Public Service (APS) in Tempe, AZ couples a solar concentrating dish, an external combustion engine and a Proton HOGEN® 300 hydrogen generator. The system was installed and operating from May of 1999 through the end of the Phase I program in December of 1999. A description of the technical performance of the system and a market assessment is detailed in the Final Technical Report [1].

Approach

The Phase I demonstration efforts and market evaluation has shown that a hydrogen generator coupled with some form of renewable power and some form of energy conversion device has a distinct advantage over a battery system backing up the same renewable application. Proton cannot determine which renewable technology will win out in the end, nor predict which energy conversion device will be the most cost effective. However, it is clear that the link to these

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alternatives lies in the ability to convert excess renewable power into hydrogen and have the hydrogen available for conversion back to power, on demand.

To that end, Proton will utilize Phase II funding to begin significant cost reduction efforts on the hydrogen generator product line that will reduce the cost of the hydrogen generator family by 50% in the next two years and show evidence of further reductions in the years beyond. Cost reduction efforts will focus on three key elements of the electrolyzer: the electrolysis cell stack, the power conditioning and renewables interface, and the system components. These reductions will be implemented on the smaller HOGEN 40 (6 kW electrical power in) electrolyzer first and expanded to the larger HOGEN 380 (60 kW electrical power in) electrolyzer towards the end of the program. All of the improvements undertaken on this program will benefit the full line of electrolyzers so that the cost to large and small energy storage applications will be reduced.

Long Term Goals

All of Proton's cost reduction goals are focused on the long term markets associated with sustainable power. However, there are three other markets where the hydrogen generator technology fits well and where products can move into commercial applications while the renewable technologies mature, come down in cost and become more commercially available.

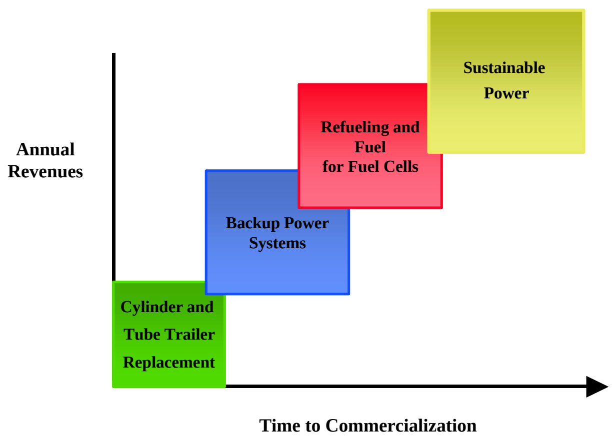

Figure 1 – Market Scope and Timing

These markets all have unique attributes that require different cost structures and pricing to compete effectively. Based on these markets and Proton's internal projections for numbers of units, market share and earnings, a detailed cost reduction plan was developed. The plan, as it pertains to hydrogen generators, focused on the HOGEN 40 and the HOGEN 380 sized units with the near term emphasis on the HOGEN 40.

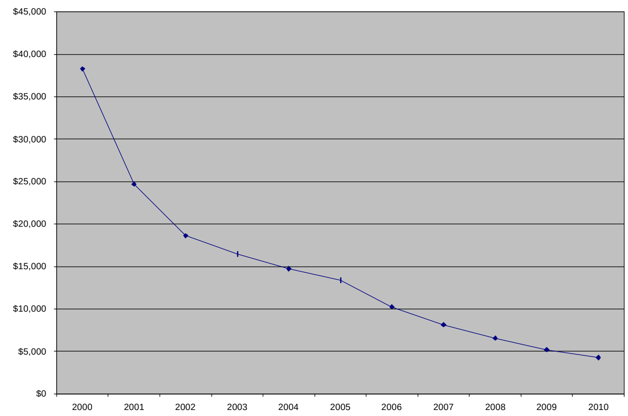

Figure 2 –HOGEN 40 (6kW) Ten Year Cost Projection

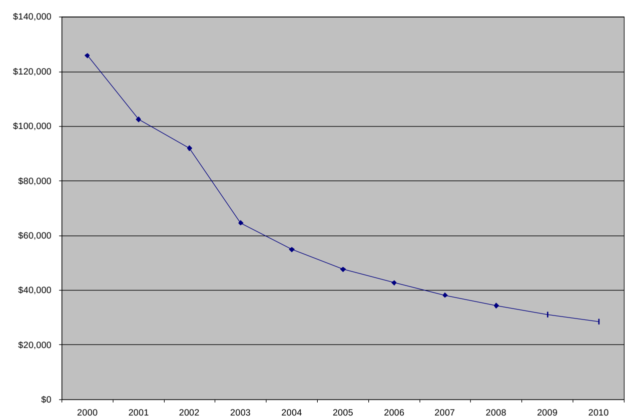

Figure 3 –HOGEN 380 (60kW) Ten Year Cost Projection

The hydrogen program has a goal of hydrogen production at the lowest possible cost. To that end, Proton has established a cost goal of $1000 per kW in the near term and $500 per kW within ten years. The goal of $1000 per kW is achieved rather quickly on the larger generator, but requires a few more years on the HOGEN 40. This is not unexpected, as the economies of scale on the larger unit are much more favorable than on the smaller unit. Regardless, both units project costs that are comfortably under $1000 per kW by 2010. The following sections will discuss in further detail the areas of cost reduction under the current agreement.

Electrolysis Cell Stack

The cell stack is the heart of the system and requires the most amount of technology development to realize significant cost reduction. Although significant government-sponsored research has focused on component cost reduction in fuel cell stack designs, there has been little emphasis on similar cost reduction efforts for PEM electrolysis stack components. This task will focus on addressing the electrolysis cell stack on a component-by-component basis using strategies that have been substantially proven in fuel cell hardware. Subtasks will address support components, membrane and electrode assemblies and flow fields. Individual component-level activities are further described below.

Support Components

The electrolysis cell stack has traditionally used machined endplates and a spring washer configuration on tie rods to maintain proper mechanical compression on the individual cell components. Work will be done to redesign the endplates for implementation of a near-net-shape process such as casting or powder metallurgy that minimizes the amount of material that is used and further reduces process time. Different materials of construction of the compression hardware will be explored and the required tooling will be purchased for the 0.1 square foot cell stack design (smaller stack) and then expanded to include the 1.0 square foot cell design (larger stack) upon successful prove out of the smaller design. In addition, design work to investigate alternate methods of mechanical compression will be conducted and evaluated on the smaller stack. If successful, this design approach will then be applied to include the larger stack.

Membrane & Electrode

This task will optimize the membrane and electrode assembly (MEA’s). This will include optimization of the amount of catalyst applied to both the hydrogen and oxygen sides of the electrode as well as the method of those applications. Techniques for catalyst application that will be investigated will include certain approaches utilized in the manufacture of fuel cell MEA's such as silk screening of inks and application of dry powders. State-of-the-art electrolyzer oxygen electrodes that are generally proprietary precious metal formulations will be used instead of typical fuel cell grade platinum/carbon materials. Membrane materials showing significant cost savings and performance enhancement opportunity will be evaluated as part of this program task. These materials may include thinner perfluoroionomers, modified styrene based materials, and composite structures. The targeted evaluation protocol will determine if these materials can withstand the life requirements and high differential pressures associated with electrolysis operation. This evaluation will include cycle testing of these materials in small test cells as well as non-operational performance characterization tests such as MEA resistance and gas diffusion.

Flow Fields

This task will further development of a lower cost electrode support material and implement advanced configurations previously concepted by Proton. This involves the characterization of materials that are electrically conductive, corrosion resistant, mechanically robust and offer the proper fluids carrying capability required for high performance. Testing will include short-term corrosion and performance testing in cells as well as benchtop characterization testing which includes porosity, tensile, resistivity, and thickness testing.

Power Conditioning and Renewables Interface

Power Electronics

This task will look for innovative ways to reduce the cost of the cell stack power supply and associated electronics as well as improving its efficiency. The power supply currently represents about 10-15% of the system material cost. Overall system efficiencies such as cells vs. current will be investigated in order to determine the optimum cost per kW we can provide. Design work will look to integrate many of the parts of the current power electronics design into the two systems to eliminate redundant framework and components.

Alternate Energy Inputs

It is imperative that the HOGEN be able to ultimately operate with a number of different renewable technologies. This task will look at various types of renewable inputs and the potential impacts on interface and operations. Various technologies and sources of supply will be contacted including the Phase I partners.

System Cost Reductions

Circuit Board

This task will evolve the controllers that are currently used on-board the electrolyzers into a circuit board design that will also serve to eliminate many of the electrical control monitoring that currently requires many discrete components and quite a bit of labor to wire. This will involve use of an outside board design house to take a baseline design used on Proton's smallest electrolyzer and add the required functionality first to the HOGEN 40 and then to the HOGEN 380. The complex nature of the system safety controls and functionality as the unit gets larger requires that this be done in a two step process.

Component Cost Reductions through Casting and Manifolds

Pressure vessels in the HOGEN system, including the hydrogen-water separator, are machined from 316 stainless steel plate and pipe stock and welded to make the completed assembly. Valves, gauges and other small hydrogen and water components are plumbed together in a discrete manner with many fittings. The goal of this task is to effect significant cost reductions in the HOGEN fluid system by going to a powdered metal 316SS casting for the hydrogen-water separator. Use of manifold mounting of components on the hydrogen water phase separator or by using an alternate component manifold will eliminate fittings and permit use of less costly manifold mount valves and components.

Project Status and Plans for Next Year

The Phase II efforts were awarded May 1, 2000. Proton has been initiating efforts on the electrical control board, low cost endplates and spring washer designs, testing of various cell stack component configurations and characterization of various renewable inputs. Other efforts as previously described will be initiated in the coming months.

As the project advances into the coming years, all cost reductions will be verified on the HOGEN 40 to ensure that they meet the product life and integrity requirements, and that they also result in the expected cost reduction. As this occurs, the item will be introduced into production and the cost reduction effort will be advanced to the HOGEN 380 product. Cell stack cost reduction efforts will be introduced as they mature to the point where their life and performance data can be adequately characterized.

In addition, Proton will research additional methods to reduce the cost curves presented above to target costs of under $500 per kW before 2010.

References

1. Friedland, R., Smith, W., Speranza, A., January 2000. *Integrated Renewable Hydrogen Utility System*, Phase I Final Technical Report and Market Assessment PES-T-99014.

Listing of Figures