Wind-to-Hydrogen (Wind2H2) Project

Boulder, Colorado, USA

The U.S. National Renewable Energy Laboratory (NREL) and Xcel Energy launched a demonstration wind-to-hydrogen (Wind2H2) project that uses electricity from wind turbines and photovoltaic (PV) panels to produce and store hydrogen. Located at NREL's National Wind Technology Center, the new facility closely links wind turbine and PV electricity to electrolyser stacks using NREL-designed, built, and tested power electronic converters. The power converters track the maximum power point of the wind turbine and PV sources in order to extract the maximum amount of energy and then pass the electricity through water to split the liquid into hydrogen and oxygen. The hydrogen is compressed, stored, and used later to generate electricity from an internal combustion engine (ICE) generator or fuel cell, or further compressed to refuel a fuel cell vehicle.

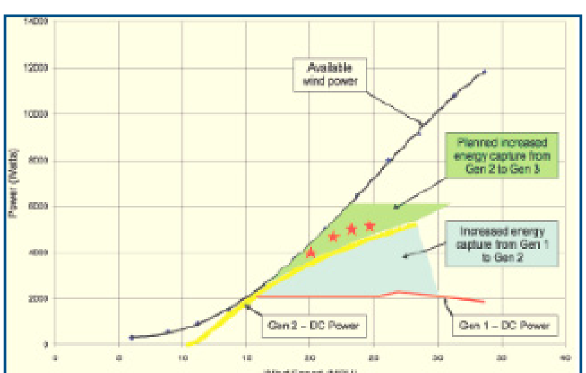
Objectives

NREL's Wind2H2 Project aims to improve the system efficiency and reduce the capital costs of producing hydrogen from the renewable resources of wind and solar in quantities large enough and at costs low enough to compete with traditional energy sources such as coal, oil, and natural gas. Their further goals include:

- Exploring system-level integration and optimization opportunities for renewable energy-based electrolysis production facilities.
- Quantifying system-level efficiency improvements and cost reductions achieved by designing and building integrated power electronics to closely couple wind turbines and PV arrays to the electrolyser stacks.
- Gaining operational experience of a hydrogen production facility, evaluating appropriate safety systems and system controls for safe operation, and identifying areas for cost and efficiency improvements.
- Evaluating the ability to integrate renewable energy from variable-output wind turbines and PV arrays and exploring the potential of using hydrogen as an energy storage mechanism.
- Determining the system impacts, efficiency, and ability of each electrolyser technology to accommodate the varying energy input from wind turbines and photovoltaics.
- Producing fuel cell-grade hydrogen while minimizing the production of greenhouse gases or other harmful by-products.
- Compressing and storing hydrogen for use during peak demand.

Approach

NREL is examining the issues related to the integration of these technologies as well as the operation and response of commercially available electrolysers being supplied varying stack current from the NREL-designed power converters. Two 7-kW HOGEN 40RE proton exchange membrane (PEM) electrolysers (2.25 kilograms per day) from Proton Energy Systems, and one Teledyne HMXT-100 alkaline electrolyser (12 kg/day)



Energy transfer improvements from the 10-kW wind turbine tested by NREL; the graph shows continued improvement, including the latest preliminary third generation improvement in the green-shaded area

Project Overview

What

Wind2H2 Project

Who

U.S. National Renewable Energy Laboratory (NREL) & Xcel Energy

When

Started: 2007
Completed: 2010

Participants

United States

Renewable Technology

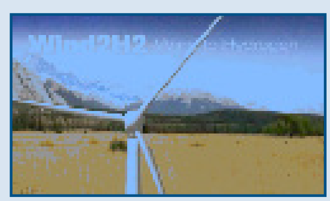
This project demonstrates hydrogen production from wind and solar-generated electricity.

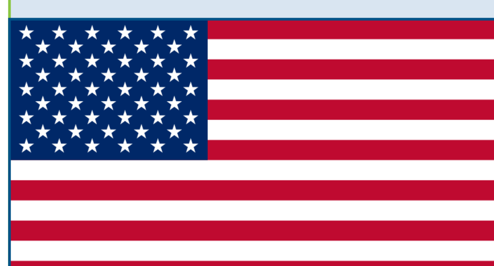
Application

Renewable energy storage and vehicles

Website

http://www.nrel.gov/hydrogen/proj_wind_hydrogen.html





produce hydrogen and oxygen from water at pressures from 150 to 200 psi (10 to 13 bar). Once produced, compressed, and stored, the hydrogen gas can be converted to electricity and fed back to the grid using the 60 kW ICE generator from the Hydrogen Engine Center. The electricity will be routed into the utility grid during peak demand hours. The Wind2H2 system also includes a second compressor, higher pressure storage tanks, and a hydrogen dispenser to allow fueling of hydrogen fuel cell or ICE vehicles.

The Wind2H2 project uses two wind turbine technologies: a Northern Power Systems 100-kW wind turbine and a Bergey 10-kW wind turbine. Both have variable speed options; the blade speed varies with wind speed, producing alternating current (AC) that varies in magnitude and frequency (known as wild AC) as the wind speed changes. The energy from the 10-kW wind turbine is converted from its wild AC form to direct current (DC) and is then used by the electrolyser stack to produce hydrogen from water. The 10-kW PV array is configurable to produce DC voltage between 60 and 240 V. Since this voltage is too high for the electrolyser stacks, NREL has designed, built, and tested maximum power point tracking (MPPT) power electronics to make the DC-DC conversion. Currently, the AC power output signal from the 100-kW wind turbine is monitored at the Wind2H2 Control Building and conditioned to directly drive the stack current of the 33-kW alkaline electrolyser stack.

Accomplishments

Energy transfer optimization:

- NREL engineers are investigating how to maximize renewable energy use and optimize energy transfer within the Wind2H2 system by designing and incorporating dedicated power electronics packages.
- NREL also investigated energy transfer from the 10-kW solar PV array, comparing a direct-connect from the PV array to the electrolyser stack with a connection through an MPPT power electronics package designed and built at NREL. The measurements showed that, in all cases, the system employing MPPT electronics captured 10 to 20% more energy than the direct-connect configuration.
- To improve energy transfer within wind-turbine-based renewable energy systems, NREL has designed and continues to test improved AC-DC power electronics systems for a 10-kW wind turbine connected to a PEM electrolyser stack. The test results, shown in the graph on the previous page, indicates continued improvement from the Gen1 to the Gen3 design (based on Gen 3 preliminary data).

Reduced Cost:

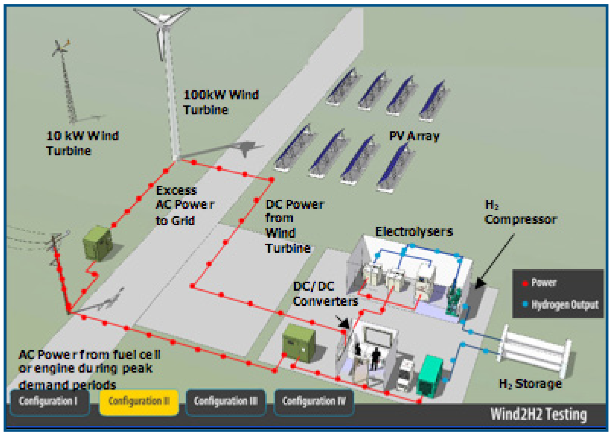
- Based on investigations, NREL engineers estimated that optimizing power electronics in large-scale, wind-based renewable electrolysis systems could reduce the cost of wind-to-hydrogen production by 7%, from $6.25/kg to $5.83/kg. System-level integration of renewable energy sources and electrolyser stacks can improve energy transfer within the system, increasing system efficiency and lowering overall cost of production.

Efficiency Measurements:

- The Wind2H2 Project found PEM electrolysers to be more efficient than alkaline electrolysers, contrary to expectations. At full stack current, the PEM electrolyser had a system efficiency of 57% HHV. At the rated stack current, the alkaline system had a system efficiency of 41% HHV. Worthy of note, the measured hydrogen flow from the alkaline electrolyser was 20% lower than the manufacturer's specifications. If the full hydrogen flow was measured, the alkaline system efficiency would have reached 50% HHV (HHV = 39.4 kWh/kg).

Lessons Learned

- ***System Integration:*** More research and engineering design related to renewable electrolysis system integration would improve energy transfer and overall system efficiency and would reduce system complexity and capital costs. The development of optimized power electronics packages is a promising area for system-level improvements.
- ***System Communication:*** Creating renewable electrolysis systems requires that equipment from a wide range of manufacturers work together as a single system. Future renewable electrolysis systems would benefit from an open-architecture approach to component development, including the development of consistent communications protocols.
- ***Codes and Standards:*** Developing clear and consistent codes and standards will expedite implementation and reduce the cost of renewable electrolysis projects.



Schematic showing operation of the Wind2H2 system when powered by the 100 kW wind turbine

International Partnership for Hydrogen and Fuel Cells in the Economy