Solar Hydrogen Project at Neunburg vorm Wald, Germany

SWB
A member of the Bayernwerk Group

Hydrogen as an energy medium: Production and storage

Solar electric current splits water in two

The idea of making use of solar energy to electrochemically decompose water and thereby obtain hydrogen for use as an energy medium is compelling on several grounds. Sunlight and water, the starting materials, are freely available. The environmental impact of the method is minor by comparison with other energy conversion processes. Hydrogen is well suited as a medium to temporarily store energy for periods when the sun does not shine and is also readily transported to its place of actual use. A disadvantage that needs mentioning is the sensivity of water electrolysis units to wear due to repeatedly alternating load and their high specific energy consumption.

In the electrolysis of water, an electric current is passed through, for example, an electrolyte solution of water and potassium hydroxide or other alkali, decomposing the water into its constituent elements hydrogen and oxygen. The process takes place in an electrolytic cell by applying a direct current to the two electrodes, anode and cathode, at either end. Hydrogen forms at the cathode and oxygen at the anode. A diaphragm separates the two halves of the cell to keep the two gases from recombining into water. Each gas is cleaned of entrained liquid in a separator. The alkali solution is returned to the cell and the water consumed to produce the gases is replenished. Power input to produce 1 cubic meter of hydrogen in a commercial water electrolyzer is about 4.5 to 5 kilowatt-hours.

Load transients stress the electrolyzer

Conventional electrolyzers are designed to run continuously at a more or less constant rate. Solar power creates quite the opposite conditions. Current intensity drops with every passing cloud and a regular day-night rhythm is a fact of life. In other words, electrolyzers to run on solar power must be designed for long-term performance under frequently changing conditions of operation.

Three electrolyzers of about 100 kilowatts electrical duty, each working to a different technical concept and capable of producing about 25 cubic meters of hydrogen an hour, were tested at Neunburg vorm Wald, Germany.

One of the two low-pressure electrolyzers installed performed well and continues in operation to collect long-term experience. The second unit had to be decommissioned in June 1995 owing to severe degradation of the membrane diaphragms, resulting in purity of the product gases falling short of safety standards.

With a view to subsequent storage of the hydrogen, electrolysis at a pressure around 30 bar (a car tire is inflated to 2 bar) has its advantages, as it saves having to separately compress the product gases. A pressure-type electrolyzer was accordingly installed as the third test unit. Start-up difficulties afflicting this electrolyzer were incomparably severer than on the two other prototypes. Satisfactory operation has however been attained in the meantime after making a number of improvements and twice changing the cell stack design.

Different ways of storing hydrogen

The hydrogen and oxygen gases produced in the electrolyzer are saturated with moisture and each contains a small amount of the other gas due to diffusion between the cells. Before being stored in outdoor vessels, the gases are therefore dried. Whether they require purification depends on what their intended use is. At SWB the impurities are removed by catalytic combustion and the gases then filled into storage pressure vessels at up to 30 bar. Two large outdoor pressure vessels hold a total of 5,000 cubic meters. Other methods of storing hydrogen used and tested at the site are liquid hydrogen tanks and metal hydride storage, in which the hydrogen is absorbed by a metallic powder.

Hydrogen can also be stored in large volumes. Underground caverns or gasometers are appropriate for very large quantities. Stationary pressure vessels are used for medium storage capacities. Smaller gas quantities can be filled into portable cylinders made of steel or carbon fiber-reinforced composite materials at pressures up to 400 bar. Metal hydride is capable of absorbing about two percent of its own weight of hydrogen.

When using hydrogen as a car motor fuel, one main point of interest is the distance the vehicle will run on a full tank. In terms of volume, hydrogen has a much lower fuel value than gasoline, meaning that a considerably larger volume is needed to give the same range. As much hydrogen as at all possible must therefore be packed into a car fuel tank. The best way of doing so is to fill liquid hydrogen into an insulated tank at minus 253 degrees Celsius temperature. The highly efficient insulation will prevent loss of fuel by evaporation over a period of about three days in a stationary car. Work is proceeding on further improvement to vehicle fuel tanks.

Small-capacity installations for electrolysis of water and pressurized storage of hydrogen gas can generally be located wherever they might be convenient. Hydrogen liquefaction facilities, in turn, are only economically viable in the center of a wide supply region.

Work still needed on electrolyzers

Varying experience was recorded by SWB in testing electrolyzers for production of hydrogen from water. With the most recent cell technology, the prototype pressure-type electrolyzer is operating as intended. Good results were obtained with the two low-pressure electrolyzers, particularly the alkaline type, the membrane type having to be decommissioned in 1995. Both equipment suppliers have since abandoned this field of activity.

Results of investigations with the gas treatment and storage systems were entirely useful. For the most part, problems arising in connection with these systems affected the compressors, which were not operated continuously, and components of the decentralized process control system. They were however all mastered.