FARM PROJECT OVERVIEW

Solar energy to power an electrolzyer, which uses electric current to break down water into hydrogen and oxygen.

SIZING THE SYSTEM

About 5 gallons of diesel are needed to farm an acre/year for corn and 3.5 gallons for beans. A kilogram of hydrogen gas has about the same energy content as a gallon of diesel. A pound (.45kg) of hydrogen at atmospheric pressure is about 194 cu. ft. in volume.

As a result, it was calculated that we would need 3000 pounds of hydrogen a year to farm the 320 acres when half was in corn and the other half in beans.

This would require 77 kilowatts of electrical power, assuming that over a year the solar panels provide power on an average of 5 hours a day. Dennis Crow, who farms the land, estimated that he uses half of his fuel for planting in the spring and half in the fall at harvest time.

The growing season is about 150 days, which meant that I would need to generate 10 pounds of hydrogen a day and be able to store 1500 lbs. in tanks. It was figured that during the other 215 days we could generate enough hydrogen for spring planting.

After looking at what the costs of an operational system would be, and the quality of the numbers that were used in sizing the system,

It was concluded that a demonstration solar-hydrogen system that provided 10% of what would be required to fuel all the farm operations. From the actual data we would gather we could refine what would be required for an operational system.

A HYDROGEN FUELED TRACTOR

Farmer was interested in having a tractor that he would use under full power in the field rather than just to drive in parades. Because of the limited hydrogen generated, our hydrogen tractor is capable of being used for 10% of the farm operations.

It was planned and started out assuming that It could obtain a diesel tractor and have it modified to run on hydrogen. Companies are working on having diesels run on hydrogen, but are years away from having a product. New Holland has developed an award-winning fuel cell powered tractor, but the costs of obtaining a tractor powered by fuel cells is prohibitive.

We contacted a supplier , who has been making Internal Combustion Engines that are modified to run on hydrogen gas. They agreed to provide a Ford 460 cu. in. V-8 engine design that could be installed in a tractor and used in the field. We selected and purchased a John Deere 7810 tractor. The four hydrogen tanks are sized to contain enough fuel to operate the tractor at full power for four hours before refueling.

We initially agreed to include a small propane tank on the tractor that could be used as “back-up” if Dennis ran low on hydrogen fuel while in the field. The engine would operate on either hydrogen or propane. In later meetings we agreed that we would instead include a small back-up ammonia tank on the tractor and have the ability to switch between powering the tractor with hydrogen or ammonia.

I wanted to have a completely renewable fuel generation capability rather than purchasing ammonia. In late 2013, I discussed the idea of generating ammonia from solar power. I found that we annually apply ammonia to the corn cropland that contains 5600 pounds of hydrogen. I decided to make the ammonia reactor and added the other ammonia subsystem hardware. The demonstration ammonia generation subsystem makes ammonia from hydrogen and nitrogen, that is separated from the air, and is stored in a small tank that can be used is use to fuel the tractor or be applied to the corn cropland.

SAFETY A PRIORITY

Maximizing personnel and equipment safety has been paramount during the design and development of the system. Historically the public is afraid of hydrogen because of the “H” word: Hindenburg. The newly issued National Fire Protection Association Document 2 “Hydrogen Technologies Code 2011 Edition” has provided the safety related guidance in the development of the system.

The electrolyzer contains interlocks to shut off the unit should hydrogen escape and the insulated electrolyzer room is designed to allow any hydrogen that could escape to easily vent out a roof opening. All the hydrogen is stored outdoors. There is no electrical power in the hydrogen storage area as the pumps are driven by compressed air. The room in which the tractor can be stored is vented through a rotary vent in the roof.

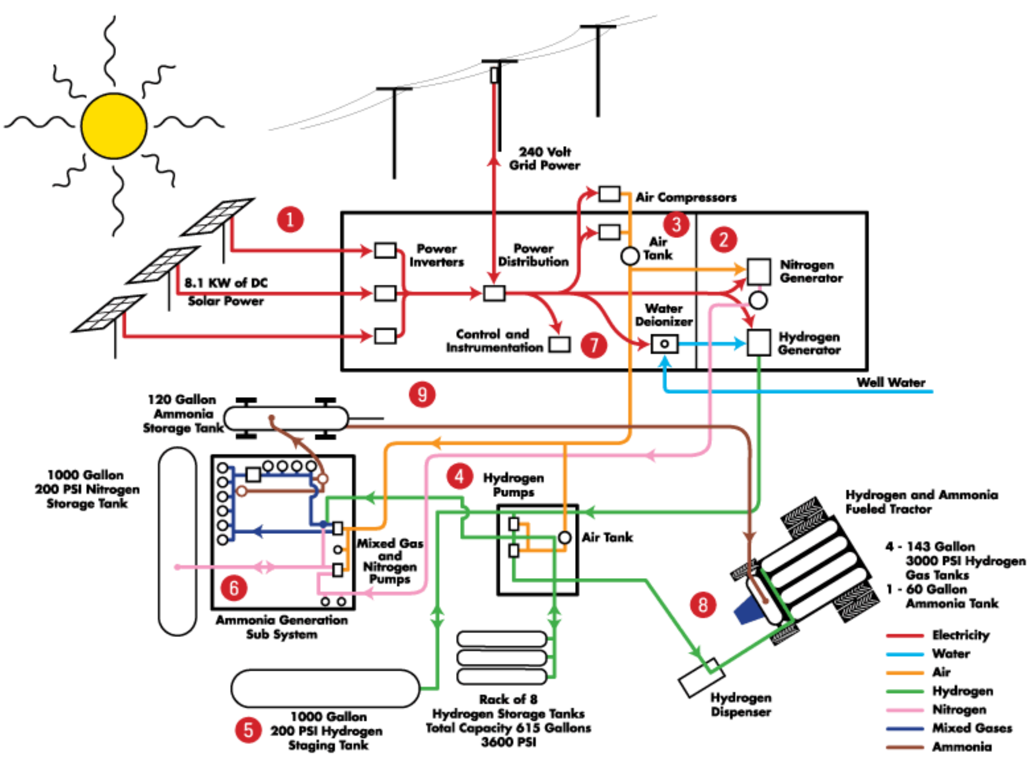
The centerpiece of the solar-hydrogen system is a John Deere 7810 tractor outfitted with a modified Ford 460 cu. in. V-8 engine. It runs on hydrogen gas or a combination of hydrogen and ammonia.

The Power subsystem includes three sets of 12- 3' x 5' solar panel modules mounted on two-axis tracker assemblies. The trackers follow the movement of the sun.

The solar panels feed energy to the main system building, which houses the power inverters, air compressors, water purification, electrolyzer, environmental control, and control and instrumentation equipment.

IMAGE GALLERY

A 1000-gallon staging tank (background) stores hydrogen generated by the electrolyzer. The eight composite storage tanks contain compressed hydrogen gas.



1. Electrical Power: Three two-degree-of-freedom solar trackers, each carrying 12 solar panels, are contained in a fenced area. The combined output is rated at 8.1 kilowatts. The average daily power available from panels is roughly equivalent to that available during a clear midday five-hour time period. Each array feeds its Direct Current power to an inverter in the equipment room where it is converted to alternating current power. Power not used is fed to the grid.

2. Gases Generation: Water from a nearby well flows through a deionizer for purification before entering a hydrogen generator. A nitrogen generator receives compressed air and makes pure nitrogen that flows to the nitrogen pump. At lower solar power levels, less hydrogen is generated. The oxygen is vented and the hydrogen flows to the storage tank.

3. Air Compressors and Air Tanks: Air, compressed by commercial electric air compressors, is used to drive the hydrogen, nitrogen, gas mixture pumps and nitrogen generator. The air is routed through a storage tank, desiccant and refrigeration dryers, and surge tanks.

4. Hydrogen Pump Assembly: A small, vented steel building houses two compressed air driven pumps and a surge tank. The storage pump is used to pump hydrogen from the staging tank into the storage tanks. After hydrogen is bled into the tractor tanks, the tractor pump is used to pump hydrogen from the storage tanks into the tractor hydrogen tanks.

5. Large Tanks and Piping: Stainless steel piping connects the 1000-gallon steel hydrogen staging tank, eight 10-ft.-long composite hydrogen storage tanks, and the 1000-gallon steel nitrogen storage tank. The ammonia storage tank contains 100 gallons of liquid ammonia that can be used for fueling the tractor or fertilizing three acres of corn cropland. The tractor contains four 10-ft.-long composite tanks containing 80 pounds of hydrogen and one ammonia tank containing 50 gallons of ammonia. The ammonia tank contains half of the energy that's in the hydrogen tanks.

6. Ammonia Generation: A small, vented steel building houses part of the instrumentation and control assembly and the components used to generate ammonia from nitrogen and hydrogen. Specifically: nitrogen and mixed gas pumps, surge tanks, inlet cylinders, feed cylinder, N2 pressure cylinder, outlet cylinder, collector tanks and control valves.

7. Control and Instrumentation: The unit's control panel enables the selection of only solar or a combination of solar and grid power to operate the air compressors, air drying equipment, hydrogen and nitrogen generators, ammonia reactor and electronics. The air compressors, pumps, generators and reactor can be set for manual or automatic operation. The computer uses solar, gas pressure, temperature and collector tank data to control system functions. A display panel showing system performance information can be monitored via the internet.

8. Tractor and Tractor Fueling: The John Deere 7810 tractor is outfitted with a 9.4-liter OX Power engine based on a Ford 460 cu-in V-8 design. It runs on hydrogen gas or a mixture of hydrogen and ammonia gases. The tractor tanks are fueled by first bleeding hydrogen from the storage tanks and after the tank pressures have been equalized, the tractor pump is used. A commercial ammonia pump is used to fuel the tractor ammonia tank from the ammonia storage tank.

9. Facility: Equipment Room: Houses the power inverters, one air compressor, the air storage tank and moisture removal components, water purification hardware, most of the instrumentation and control subsystem, and the environmental control equipment that keeps the temperature in the gases generation and equipment room above 40 degrees.
Gas Generation Room: Hydrogen and nitrogen generators.
Tractor Storage Room: Adjacent to the above rooms and contains elevated tractor workstand, the second air compressor and space for storing the tractor.
Fences: Enclose the solar array area and separately the ammonia related hardware and hydrogen storage, pumping and fill area.

The tractor is fueled with hydrogen using a dispenser mounted on an elevated work stand. Ammonia is pumped into the tractor ammonia tank from the ammonia storage tank.

The equipment room contains the rack control panel (foreground, right side), used to manually set subsystem functions to Manual, Auto or Off; water deionizer (far right corner), purifies well water for use by the electrolyzer; and hydrogen valve status board on the left back wall.

A hydrogen pump assembly contains two air-driven hydrogen pumps. One pump compresses hydrogen into the storage tanks; the other pumps hydrogen from the storage tanks into the tractor tanks.

The electrolyzer breaks down water into oxygen and hydrogen gas using a proton exchange membrane design. The oxygen is vented to the atmosphere and hydrogen is piped to the staging tank.

The controls and instrumentation assembly is located in the main system building. It directs the operation of the electrolyzer, nitrogen generator, air compressors, hydrogen fuel dispenser, hydrogen and ammonia pumps, and ammonia storage. A display panel that shows system performance information can be monitored via the Internet.

Three power inverters convert direct current (DC) produced from the solar arrays to alternating current (AC), which is used by the system components, or fed to the grid when not needed by the system. The air conditioner (in the background) cools the equipment room in the summer and maintains the electrolyzer room temperature above freezing in the winter.

Two 5 h.p. air compressors provide air to power the hydrogen, nitrogen and mixed gases pumps and to control the isolation valves. The second compressor is housed in the tractor storage room. A refrigerant dryer and desiccant canisters (affixed to wall) remove moisture from the compressed air.

A metal hut containing the hydrogen pump assembly is in an isolated fenced area separate from the main system building.