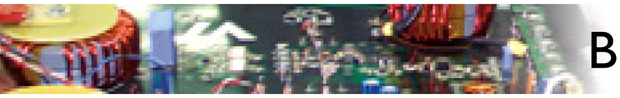
A Powerful Dream,



But it Needs EEs to Make it Work

Not only is Jason Lai working to develop technology that will make fuel cells a cost-efficient energy source, but he is also dedicated to giving students experience and is one of the instigators of the "Future Energy Challenge" competition.

Fuel cells are creating a buzz lately, touted as a zero-emission energy source for homes, automobiles, even cellular telephones. Using an electro-chemical process that converts hydrogen and oxygen to electricity, fuel cells produce waste products that are simply heat and purified water — an environmentalist's dream.

It is not hype, according to Jason Lai, an associate professor on the ECE faculty who is working on fuel cell technology for a power plant. He cites encouraging numbers: in its initial development, fuel cell energy conversion efficiency is exceeding 50 percent, compared to 45 percent for a typical large coal-powered generating plant and 22 percent for solar-powered systems, which are matured technologies. A fuel-cell powered car would yield the equivalent of 80 miles per gallon of gasoline. Fuel cells have nearly 10 times the energy density of lithium ion batteries, which are so common in portable electronics.

10x the Density, But 10x the Cost

There are a few hurdles to be overcome, however, before fuel cells achieve their potential: cost, fuel, and an EE issue familiar to many Virginia Tech engineers — power conditioning. Commercial fuel cell systems today cost between $4,500 and $6,000 per kW, compared to $500/kW for internal combustion engine or combustion turbine-based generators, Lai pointed out. Recent developments include less expensive catalysts, materials, and manufacturing, "however, the price must still be reduced by an order of magnitude." Today's fuel cell manufacturers are relatively inexperienced in manufacturing, but once they accumulate sufficient knowledge, the cost reductions will succeed, and mass production will cut costs still further, he believes.

Fuel cells are often compared to batteries, but unlike batteries, they need a constant source of hydrogen fuel. The hydrogen can be stored and used, or it can be reformed from carbon fuels, such as natural gas and methane. Natural gas is considered inexpensive and readily available in most communities, providing an easy fuel supply. Although fuel cells do not generate waste products, hydrogen reforming does and emissions vary according to the source fuel. "The waste, however, is significantly less than any combustion process," Lai said.

Converting Unpredictable, Low-Power to Commercial Needs

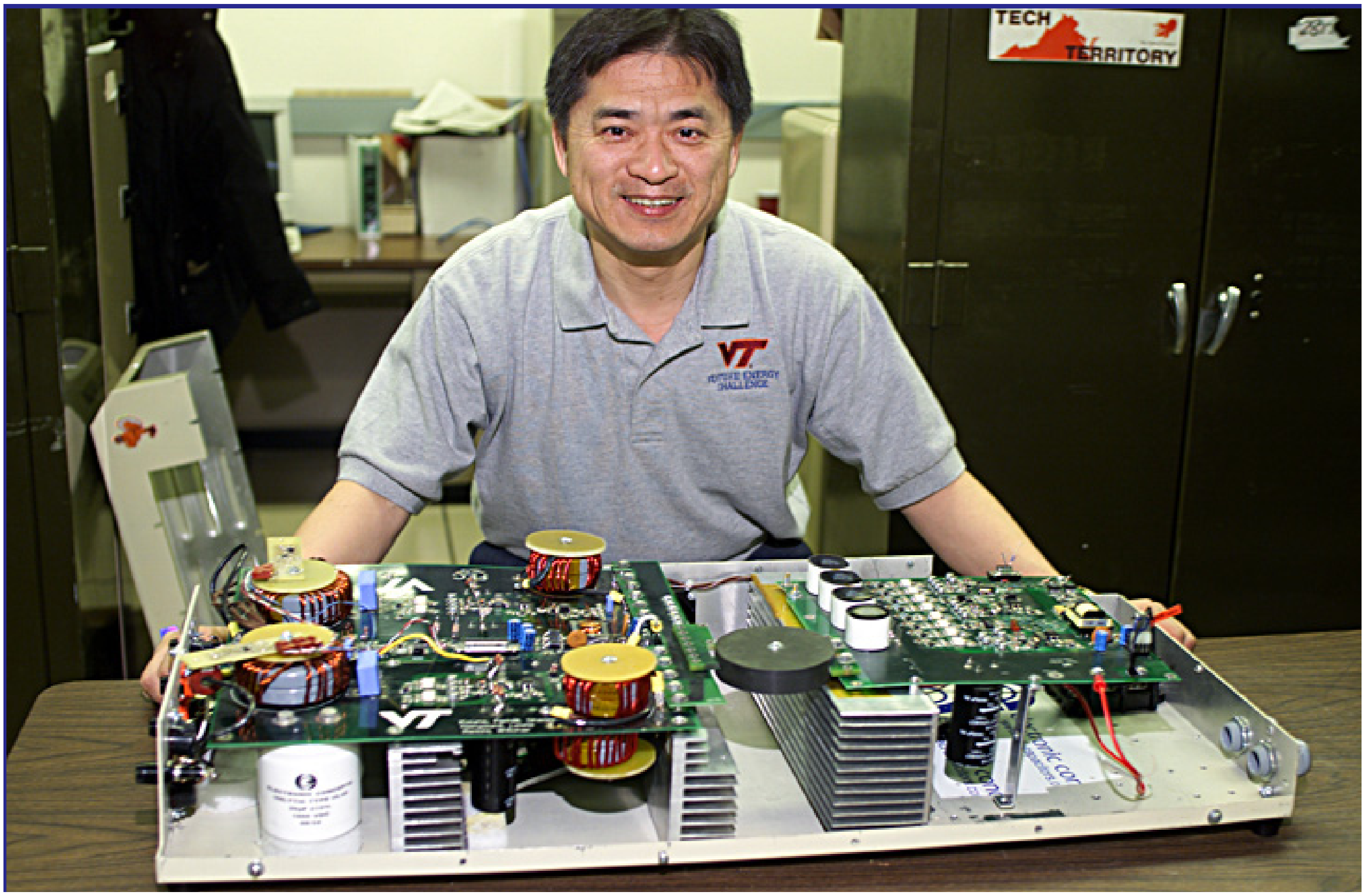
The critical issue for electrical engineers is the electrical power itself. Individual fuel cells produce DC electricity between 0.6V and 1.1V. Although computer chips can run as low as 3V, the complete laptop often requires 20-24V. Households, appliances, and equipment use 120/240V AC; commercial and industrial facilities typically require 208/480V AC; and automobiles typically run at 300V DC, he explained.

"Our first challenge is to get the source to a usable voltage level. Although we can stack many cells and connect them in series to get higher voltage, as we stack more and more fuel cells, it gets more and more challenging and we start negatively impacting the fuel cell process. Just 120V would take a stack of more than 100 fuel cells. This would be difficult to produce, more expensive, and might not be the optimal fuel cell size," he said.

"The second challenge is that fuel cells do not provide a 'stiff' power source." There are inherent voltage variations from fuel cells, plus fuel cells do not respond quickly. "It's not like a battery, where you get immediate power. The fuel flow can run slowly and you have a time delay. If you suddenly turn on a light, using a fuel cell, the light will not go on immediately and, when it does, it will be gradual," he said. "A time delay from the source to the load makes the fuel cell power plant design quite challenging.

"So, we are facing high-power, AC needs and a low-power, DC source that provides unpredictable, slow electricity. That's a challenge for the fuel cell inverter," he said.

Lai is involved in several such challenges. One of the fuel cell projects is an effort for the U.S. Department of Energy Solid-State Energy Conversion Alliance (SECA) to develop a solid oxide fuel cell with a 22-50V DC output, then step it up to 400V. They will then develop an inverter to convert the output to 120/240V AC.



Jason Lai exhibits the DC (left side)-to-AC (right side) fuel cell inverter that was developed by a Virginia Tech student team for last year's Future Energy Challenge. This year's team is designing a fuel cell inverter for an off-the-grid home. Lai serves as a steering committee member of the international competition.

Getting Students Fuel Cell Experience

Lai is also interested in giving students experience with what he believes is tomorrow's technology. He was the founding chair for the 2001 Future Energy Challenge, first of its kind in power electronics design competition, and is one of the steering committee members of the 2003 Future Energy Challenge, in which teams from 19 competing universities are designing and building prototype energy and motor systems for home use. He serves as an advisor to the Virginia Tech team, which is building a prototype solid oxide fuel cell inverter system for an off-the-grid house.

The fuel cell developed by the SECA Industrial Team provides DC power between 22-50V at about 250 amps, but the design goal is to deliver a continual 5kW of power at 120-240V output and handle a 10kW peak load. Moreover, the target costs of the inverter are $40 per kW with greater than 90 percent system efficiency, whereas off-the-shelf power supplies are typically sold at $1,000 per kW and 75 percent efficiency. "Efficiency is emphasized in this competition," Lai said, "because less fuel will be consumed and fewer fuel cell modules will be needed."

Emphasis on household power matches a DOE goal for fuel-cell applications. "In order to bring down the total cost of fuel cell systems, they need to be used in a big market where mass production is involved," he explained. He described that early hopes were pinned on automotive fuel cell use. "Several years ago, car manufacturers were predicting that we would be driving fuel-cell powered autos by 2003. Well, it's 2003 and only a total of two such commercially available cars are on the road — both built by Honda and sold in California."

In looking for another large market, the stationary power for housing and commercial buildings was identified. With greater, more constant power needs, it could be even larger than automobiles, he said. "It has a great potential, so it's being pushed today," he added.

Is the Real Potential in Portable Power?

"Suddenly, in the past two years a newcomer has arisen: portable power. The demand for portable power for notebooks, cell phones, and wireless electronic devices is very high and manufacturers and developers are running up against the limits of battery power," he said. Major electronics companies have recently formed small groups to look into fuel cell power, he noted. "Imagine never having to recharge your battery, but just add fuel and go."

He believes that portable power has the potential to be the largest driver of fuel cell technology. "Consumers are used to paying a premium for portable devices. The extra cost of power can be absorbed. The market is huge," he concluded.