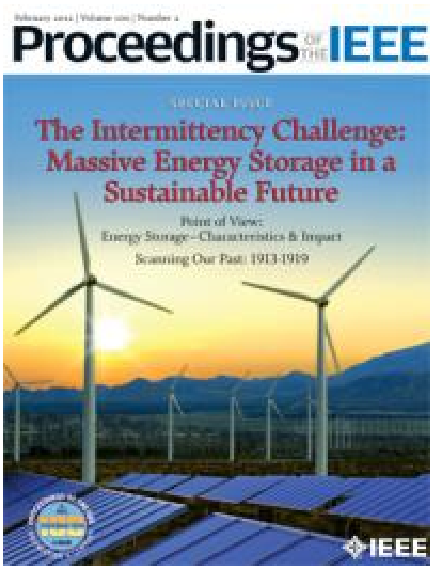
Finding solutions to Achilles' heel of renewable energy: intermittency

March 6 2012, By Diana Lutz



(PhysOrg.com) -- William F. Pickard introduces the February 2012 special issue of the *Proceedings of the IEEE* by quoting the Bible: “The wind bloweth where it listeth.” That, in so many words, describes is the major technological issue with renewable sources of energy, such as solar and wind power.

“Wind turbines or solar collectors alone cannot supply baseload power,” Pickard says. “It’s blowing beautifully outside today, and if you had a wind turbine you’d be in fat city. But at sundown the wind could suddenly drop and there'd be no sunshine to replace it. You would freeze in the dark – unless you had stored up energy."

Intermittency, sometimes called the Achilles' heel of renewable energy, has so far limited the penetration of renewable sources in most power grids.

Pickard, PhD, senior professor of electrical and systems engineering in the School of Engineering & Applied Science at Washington University in St. Louis and a life fellow of the IEEE, co-edited the special issue, "The Intermittency Challenge: Massive Energy Storage in a Sustainable Future," with Derek Abbott, PhD, professor in the School of Electrical and Electronic Engineering at the University of Adelaide and a fellow of the IEEE.

"Most projections show that late in the 21st century, fossil-fuel shortages are going to bite hard," Pickard says. "If you're an optimist, you might say 75 years, and we're going to be in trouble — real trouble. And once economical sources of fossil fuels approach depletion, we have no certain recourse except to renewables."

What, then, can be done about the problem of intermittency? The Proceedings of the IEEE, the most highly cited general interest journal in electrical engineering and computer science, delves into the problem, focusing on schemes for rendering renewable energy reliable and dispatchable, particularly massive storage facilities for energy.

Pickard, who is retired from teaching, is motivated not by his own welfare but by his grandson's. "In 70 years, he says, you and I will be dead, but my grandson might be left sitting with no energy resources. What benefit has he received from this dissipation of fossil fuels? I got a benefit, you got a benefit, but he gets the ashes."

Transnational power grids

One of the more ambitious articles in the issue describes a giant power grid, to be called the Pan-Asian Energy Infrastructure, that would encompass China, Japan, South Korean, the 10 Association of Southeast Asian Nation (ASEAN) states and Australia.

Wind energy is abundant in China and Mongolia, and solar energy is abundant in Australia's interior. Together, the authors say, they "represent Asia's most plentiful renewable energy resources for which capture technology currently exists."

With a grid this big, the authors say, averaging effects come into play and uncorrelated intermittencies can partially cancel each other out.

"Northern China's peak electricity demand occurs in winter because of heating needs. Australia's Outback solar energy resources are strongest in the southern summer, which is the northern winter. Therefore, Australia's peak solar energy output is suited to meeting China's winter heating peaks."

This is not the only transnational grid either planned or under construction.

A group of European companies and the Desertec Foundation envision that, by 2050, solar power plants in the Middle East and North Africa will satisfy 70 percent of the area's electricity needs and 17 percent of the electricity needs of the European Union and some neighboring countries.

The solar energy would be transmitted across North Africa and connected to Europe across the Mediterranean Sea. Construction of the Desertec's first 500-megawatt solar farm in Morocco is scheduled to start in 2012.

Ultrahigh-voltage DC power transmission

But, says Pickard, you can’t ship power over extremely long distances through interconnected synchronous AC systems, because of stability problems. “What you get is sloshing inside the network area and sloshing will begin to take the network down.”

For long-distance transfer of bulk power ultrahigh-voltage (800 kilovolt) DC lines are needed, he says. These lines allow higher transmitted power with the same stability margins and lower losses.

The technical problems with these lines are not trivial, Pickard says, but they’re already being solved: — in China. According to the authors of an article in the Proceedings volume on ultrahigh-voltage transmission, ”China is constructing a number of high-power DC energy highways, superimposed on the AC grid, in order to transmit electric power from huge hydropower plants in the center of the country to load centers located as far as 2,000 to 3,000 kilometers away.”

Massive energy storage

Most schemes for the energy future, including transnational grids, will also require massive energy storage, some scheme to transform surplus grid energy into a different but conveniently stored form and then back-converted and returned to the grid when electric power is needed. Pickard calls them “granaries for electricity.”

By massive, Pickard means storage with a rated output power of at least 1 gigawatt and a rated storage capacity of at least 2 gigawattdays, enough to see a major metropolitan area through most emergencies.

Many of these storage schemes assume the baseload power would be supplied by concentrating solar power (CSP) systems. A CSP system uses mirrors to bring solar radiation to a hot focus that can then be used to superheat steam and run a turbine for power generation.

Surplus energy from the concentrators could be stored either chemically or thermally. Chemical systems might be based on the reversible dissociation of ammonia or on dissociated metal hydrides. Thermal ones might store the heat directly in concrete or in molten salt.

Compressed air and pumped hydro

But, says Pickard, if you look at the web) site of the Electricity Storage Association (www.electricitystorage.org), only two energy storage technologies stand out as truly massive. They are compressed air energy storage and pumped hydro.

Compressed air energy storage is really quite simple, he says. “When you have energy you don’t know what to do with, you simply compress air into a cavity under the Earth and when you need the electricity, you blow this air through a high-speed turbine, spinning a generator, and you’ve got your energy again.”

Of course, there is a catch. As anyone who has pumped up a bike tire knows, when you compress air, it heats up and when you allow it to expand, it cools down. To avoid thermally cycling your storage chamber, he says, you’d need to compress the air in stages, with counterflow heat exchangers between the stages.

“If you believe the design figures, you can get 60 or 75 percent turnaround efficiency, which isn’t bad. The only problem is that nobody has ever built a functioning adiabatic compressed-air energy-storage system,” Pickard says.

Pickard prefers pumped hydro, but with a twist. To achieve the goal of 2 gigawattdays of stored power, you'd need a reservoir that would have roughly the volume of 10 Great Pyramids, and to minimize losses and maximize power, this reservoir would have to be several hundred meters above a lower reservoir and yet close to it horizontally.

"The solution is to excavate an underground reservoir many hundreds of meters below surface level and to exchange water between it and a surface reservoir created immediately above it and diked using spoil from the excavation. This variation of hydro storage is called underground pumped hydro," Pickard says.

Such a facility could be put almost anywhere that there was low-quality land underlain with competent rock— (in industrial brownfields, for example.

But, says Pickard, "if underground pumped hydro is so great, how come it does not yet exist?" Perhaps because to displace an entrenched technology, the new technology must be clearly superior under present conditions, he says. But the superiority of pumped hydro may become "starkly manifest" only in the future.

Pickard says it is important to remember that there are moral as well as economic and technical dimensions to the intermittency challenge. If our generation lets the matter slide, "our descendants will be saddled with the detritus of a wastrel lifestyle."

More information: The entire issue is available free to the WUSTL community at: ieeexplore.ieee.org/xpl/tocres … 100&asf_sp=&asf_pn=1 . Other readers must either benefit from institutional subscriptions or purchase the issue.