Lightning in a Bottle: Storing Energy for the "Smart Grid"

by Jeremy P. Meyers

There's a scene in the science fiction comedy "Back to the Future" in which the protagonist must time perfectly the intersection of a car moving at 88 miles an hour with a lightning strike. It's a thrilling scene, even if it does play fast and loose with physics. While it makes for a great movie, it also underscores a challenge for what we require out of our electric grid: none of us could rely on the electric grid for our daily needs if we knew that we had to time precisely the turning on of appliances with a gust of wind, much less the precise position and timing of a bolt of lightning.

Harnessing an intermittent and generally difficult-to-predict source of power is a challenge, not just as a plot device for science-fiction writers, but for the engineers and utility managers whose job it is to provide electrical power to customers on the grid. While great advances have been made in the performance and specific cost of renewable resources, they still make up only a small portion of the overall generation portfolio, in part because of the challenge of dispatching those intermittent and unpredictable power sources. This is a challenge that we are only beginning to face.

What if the protagonist of "Back to the Future" jumped 25 years into his future, from 1985 to 2010, instead of 30 years into his past? He would see a world in which communications have been utterly transformed, with wireless communications and the Internet, but where power is generally generated and distributed in the same ways that it was in 1985 and still quite similar to1955. Our energy infrastructures still seem largely tied to the technologies and structure that were formative in its development in the 20th century. We have different distribution systems for thermal energy, electrical energy, and transportation. Indeed, these systems operate largely in parallel and independently of one another, as oil delivers almost all of the power to the transportation sector, and almost none to the electric grid. These systems are poised for a rejuvenation as we bring to bear new technologies and business models to make the overall network more efficient and responsive.

At this writing, oil prices are more than double what they were throughout the 1980s and 1990s, even though consumption is down from record highs as the world economy recovers from recession. The leak at the Deepwater Horizon rig is spilling oil into the Gulf of Mexico, threatening wildlife and the people whose livelihoods depend upon those waters. At the same time, the global political debate about anthropogenic global warming and how, or even whether, to respond to it, lingers on.

While the scope of energy exploration, extraction, and consumption is truly a technological marvel, there are signs that the overall method of delivery and conversion is straining in a system whose larger structure is marked by stasis. The development of the electrical grid has improved standards of living and raised life expectancy for countless millions of people, but the modern grid is still based on designs and concepts that were hammered out nearly a century ago, and isn't designed for modern electrical loads, distributed energy sources, or optimal efficiency.

At the same time that we confront an aging infrastructure, both population and economic output are increasing. Even if the world economy doesn't require the same amount of energy per unit of economic output that it once did, the overall energy demand of the planet is increasing, and that almost certainly means that energy prices will feel upward pressure as well.

And yet, even as our energy infrastructure and energy policies shows signs of straining in the face of these trends, investors are looking for the next big opportunity for innovation and new technologies to spur economic growth. Over the past few years, we have seen real growth in installations of renewable energy technologies, as well as lowered costs for power electronics and processors. The hybridization of our transportation infrastructure has begun, first with mild hybrids, and soon with electric vehicles—the first examples of our energy infrastructures exchanging power in the form of electricity. There are two forces at work that promise to completely rewire the way that we think about energy extraction and distribution: the addition of renewables to the grid and the ability to exchange information rapidly between suppliers, consumers, and distributors of energy. Harnessing these technological and market forces is akin to capturing and redirecting an immense amount of creative power on a structure that modern life relies so heavily upon.

Consider the implications of these changes: if current trends continue, solar installations on homes and businesses will become cost-effective, even without government subsidies. Wind power will proliferate. With those additions, there are additional challenges. As power conditioning and communications technologies improve, "smart appliances" will proliferate, allowing them to respond to signals from utilities about the overall performance and capacity of the grid. Carbon regulation or pricing is almost certainly coming, and when it does, electric rates will reflect the cost of carbon emissions based upon the source of electricity, giving a further boost to low-carbon renewables, even as we learn how to plan for intermittency and variability.

All of this points to changes that will, in turn, produce needs of its own—the need for storage, and alternative means of energy conversion and control that can respond to the flow of information about supply, demand, and differential pricing. Electrochemical systems offer the ability to provide fluidity to the grid—to take electricity from places and times when generation is relatively cheap, and provide it to the consumer at times when demand is high and supply is relatively low. These market needs will push technologies in new directions. In this issue of *Interface*, we look at some of the changes and some of the possibilities that the ECS community will be able to investigate in the years to come. ■

Editor's Note: A related article entitled, "The 21st Century Grid," by Joel Achenbach appeared in National Geographic*, in the July 2010 issue.*

About the Author

Jeremy P. Meyers is an assistant professor in mechanical engineering at The University of Texas at Austin. He is a winner of the UTC George Mead Medal for Engineering Achievement and the DuPont Young Faculty award. He currently serves as Secretary of the Energy Technology Division of ECS. He may be reached at jeremypmeyers@austin.utexas.edu.

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