Inching Our Way to a Smarter Power Grid

Maybe, as one expert suggests, we should focus a bit less on managing legislation, regulation, and uncertainty, and instead start leading customers to a new era of prosperity. After all, time is running out.

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The far-flung electrification of America was once described by the U.S. National Academy of Sciences as "the greatest engineering achievement of the 20th century." Yet today, in the early 21st century, terrorist threats, the digital economy, as well as global climate change and recent natural disasters such as Katrina, have all focused attention on the pressing need for an intelligent, nimble, and more reliable power grid.

If history repeats itself, efforts to upgrade and revolutionize our contemporary power transport system will mimic what happened with computers and telecommunications: smaller, cleaner, and smarter solutions. Yet there are some immense challenges ahead when dealing with an electricity infrastructure that, in many respects, has been largely stuck in time.

Consider the following startling facts:

- Electricity is big, big business. With over $600 billion in assets, the nation's electric utilities are twice as large as the telecommunications industry and almost 30 percent larger than the auto industry.
- Roughly 70 percent of these assets are power plants, most of them built in the mid-1960s with 1950s technology. Only 10 percent of utility assets are in transmission facilities, akin to electron highways. The remaining 20 percent of utility assets are in the

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poles and wires of utility distribution systems that connect power directly to people.

- Between 1975 and 2004, electricity demand grew by over 100 percent, while spending on grid upgrades declined by 50 percent.
- The largest market cap for an individual electric utility – Exelon – is $32 billion. This compares to a market cap of $365 for Exxon Mobil. Of the over 5,000 private and public utilities in business in the U.S., only 17 boast market caps of greater than $10 billion.

These facts underscore the challenges posed to revamping the highly capital-intensive business of providing a product that has become the lifeblood of modern life. The stakes are extremely high. All told, it is estimated that today's dinosaur power grid costs U.S. business and residents $100 billion every year. ''If present trends continue,'' commented Roger Anderson of Columbia University, ''a blackout enveloping half the continent is not out of the question.''

Since most of the equipment that makes up the North American grid is reaching the end of its design life after nearly three decades of underinvestment, several strategic public/private partnerships on grid modernization have been launched. Among them is the Electric Power Research Institute's IntelliGrid program, which is dominated by U.S. private and public utilities but does include Electricite de France (EdF), the government-owned French utility serving 42 million customers in 22 countries. In essence, the program pushes an open architecture for electricity similar to current common carrier platforms for telecommunications services. IntelliGrid has also been pushing the notion of a ''self-healing'' grid, one which would respond automatically to limit disturbances and boost both efficiency and performance.

''During the rolling blackouts in 2003, which started in Ohio, the utilities right next door could not see what was going on,'' said Rick Counihan, one of the early brains behind IntelliGrid, but now San Francisco manager for ECOS Consulting. As a consequence of geographical monopolies, which fostered a lack of interaction with competitors or vendors, this blackout rolled through 11 states and carried a pricetag of $6 billion. ''There is phenomenal value for companies and customers to be able to interact easily, but the historical development of geographical monopolies reduced incentives to integrate distributed intelligence in our electricity system,'' he said.

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''Right now, the grid is overbuilt in some areas and underbuilt in others,'' he continued. ''It was hard for utilities to make money off of investments in transmission and distribution in a regulated, monopoly system; hence, today's lack of progress. What we need now is more sensors tracking temperature, wind speed, and voltage to increase reliability. In premium power applications, you see the most innovation: backup power systems, batteries, distributed power generation, and redundant resources. All of these things are being done by the private sector today.''

It appears some of the advanced work on grid modernization is occurring on the West Coast. The Bonneville Power Administration, for example, pioneered the notion of an ''energy web'' that monitors grid operations via the Internet, instead of the radio-based communications used throughout most of the country. BPA also has in place a ''non-wires'' program that relies on energy efficiency improvements, demand response, and distributed generation to defer capital expenditures for the needed increase in transmission and distribution (T&D) system capacities.

Yet the most advanced in network designs is occurring on the East Coast at ConEdison, the utility serving New York City. With the financial district being located in their New York City service territory, there can be no risk of interruptions. If a circuit breaks within ConEdison's

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service territory, there is a network loop to prevent the kinds of single-point failures that would be likely in much of our current grid, where there is very little redundancy in the system.

Other East Coast innovators include Concurrent Technologies Corporation (CTC), a non-profit firm with ties to the Department of Defense headquartered in Pennsylvania. ''The sole mission of GridApp™ is to put technology in use, and not just by a single utility,'' said Paul Wang, project manager of a CTC-led utility consortium called GridApp. ''We are purposefully choosing projects where a single use can be replicated into multiple uses to have industry-wide benefits,'' he said. Among the projects developed so far is ''Substation in a Box,'' a completely self-contained electricity substation that literally looks like a big box. It carries a much smaller environmental footprint than a traditional dispersed equipment substation, and therefore could ease siting and safety concerns.

''Following the trend of deregulation, R&D budgets of most utilities were downsized. Some have lost all internal R&D functions. Cost-cutting is the major trend at most utilities, so they see the increasing importance of public dollars to now support the R&D they cannot do by themselves,'' he said.

GridApp provides the needed incentive to leverage utilities' diminishing resources, he argued. Yet the pool of government funding is insignificant, as compared to what is needed for the overall investment required in the next 10, 20, or 30 years for grid modernization—estimated in the range of hundreds of billions of dollars. Woefully, federal R&D budget outlays are still not balanced toward needs in the T&D area, as reflected in that only 6 percent of the 2005 DOE R&D budget in electricity is going toward T&D, whereas roughly 60 percent is targeted at power generation.

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There was a little bit of good news for smart-grid enthusiasts in the passage of the Energy Policy Act of 2005, which calls for nationwide reliability standards and other demand response and time-of-use metering provisions that may stimulate innovations inching us closer to the promised nirvana of an intelligent grid. Yet observers such as Patrick Mazza of Olympia, Wash.-based Climate Solutions claim that significant obstacles remain. ''Traditionally cautious utilities tend to hold back until success is demonstrated elsewhere. So technological progress stalls awaiting the courageous act of some early adopter utility, or a public–private partnership to take the lead,'' he said.

Yet another public/private effort is the Pacific Northwest GridWise Testbed, currently investigating how a fleet of so-called smart appliances might interact with the envisioned new electricity ecosystem of the future. ''Most appliances are dumb as a stone,'' commented Robb Pratt, project manager for the GridWise Testbed. ''We just launched a program whereby 400 homes will be interacting in a virtual real-time market where appliances, thermostats, and other controls will allow participants to be able to respond to price signals and reduce power consumption.''

Jesse Berst, president of the Center for Smart Energy, claims we have indeed reached a tipping point. ''Computer intelligence is less expensive than old-style capital assets,'' Berst stated simply. He pointed to studies conducted by Pacific Northwest National Laboratories and the Rand Corporation that show a shift toward an intelligent system that substitutes bits for iron could save between $50 and $100 billion over 20 years. Berst noted that other studies show that a return on investment of $4 to $8 for every dollar invested in a smart grid.

''We can't postpone this any longer,'' Berst said, noting that business-as-usual spending will fall short of what is now needed to

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make the grid modern. He estimated that investments on the magnitude of $5–10 billion annually over current funding levels will be necessary to move closer to a new era of ''designer electricity.'' Trends are beginning to move in a positive direction, he maintained, but there is much work to do.

Berst's advice to today's utilities: ''Stop spending your life on managing legislation, regulation, and uncertainty, and start leading customers to a new era of prosperity.''

Sidebar: A European View

Interestingly enough, an intelligent grid is defined a bit differently in countries such as Denmark, which currently receives up to 40 percent of its electricity from wind turbines of various sizes distributed throughout that country's grid. A government policy of mandatory access to the grid and subsidies covering 30 percent of capital investments helped spur the wind boom. Utilities even had to pay for any retrofits to accommodate all wind energy systems. If indeed we are to shift to renewable sources that are intermittent in nature, then Denmark offers some fascinating lessons about how best to manage large amounts of distributed generation, a key trend likely as the grid becomes more sophisticated.

No other country relies more on dispersed power sources than Denmark. ''They had all of these tiny turbines, many only producing 50 kW of electricity, that were invisible to the system. This was quite difficult to manage,'' observed Jayson Antonoff, a sustainable-energy consultant with International Sustainable Solutions. ''Even in Denmark, people began to say, 'This is crazy, because wind turbines were everywhere.' '' So, 10 years ago, this country shifted toward centralized wind systems, primarily located offshore. ''There are now only three pockets in the country where wind development is allowed on land. The activity on land is now focused on repowering—replacing the small, existing turbines with fewer but larger ones that are more efficient and have less (environmental) impact. All of the new development is offshore with multi-megawatt turbines,'' added Antonoff. The largest machines on the market today are 5 MW, specifically designed for offshore installations.

Back in the mid-1990s, in order to increase system efficiencies and decrease greenhouse gas emissions, Denmark required all non-wind electricity generators to produce not only electricity but heat. Denmark has since developed new policies creating a market for thermal energy. Through public policies, Denmark is seeking the right balance between thermal and electrical energy. It is really a matter of the greatest efficiency. Today, if you are an owner of a cement plant or waste incinerator, and you generate excess heat, you can sell it. Planning and construction of distribution networks for thermal and electric resources are handled by the public domain in Denmark.

Of course, Denmark, a small peninsula country with scarce power sources besides the wind, is not an island when it comes to electricity. Because of an advanced international grid, it can access hydropower in Norway to the north and coal and wind in Germany to the south so that is one way Denmark's grid operators manage the ebb and flow of wind.

But in winter – when windy storms rage – the fleet of wind turbines operating on land and offshore can sometimes power the entire country. Since the hundreds of combined heat and power (CHP) plants provide the only source of heat for many buildings, they must run during cold weather. The wind turbines may have to shutdown during the periods when they could be producing the greatest amount of energy. Unless, that is, this extra power could be exported north and south.

Antonoff summed up the differences between the U.S. and European approach to developing a smart grid in this way: ''On the technology side, the U.S. is the leader. We are great here in the U.S. at technology gadgets and figuring out how to fix things. The Europeans are much more focused on strategy and policy and how to introduce behavioral changes. They see a problem, develop a policy to address it, and assume the technologies will follow.''■

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