The Smart Grid and Beyond

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The United States today faces basic questions on its energy and electricity infrastructure – how to meet the growing thirst for electrical power; whether and how to move from fossil fuels; how much to rely on renewables, nuclear or other options; the state of the grid; and other questions that go to the heart of how the nation power its life.

Among the avenues being considered is one that would transform the relationship between power generation and use – the smart grid. When electrification made the 20th century possible, the paradigm was simple: utilities generated power, and everyone else used it. The goal was cheap power readily available and actively consumed, and by linking a multitude of generation facilities to hundreds of millions of users through an intricate distribution system, utilities made it happen with minimal intrusion into how and when power was used. Only in the late 20th century were the first steps taken to influence use. But now, by harnessing a vast telecommunications network, the smart grid vision would empower utilities to reach directly into the world of the users – residential, industrial, and commercial – to adjust use relative to generation capacity in real time.

Why the Smart Grid?
Today's grid relies heavily on 19th century technologies that, until recently, have served very well. So, what changed? Quite a bit – much of it is stunningly important.

Increasing peak demands, especially in a recovering economy and a huge commitment to plug-in electric vehicle economy, may result in generation capacity lagging behind demand in many of the nation's leading population centers. Imbalances have worsened between peak and off-peak consumption. The time and costs of building conventional power plants has risen sharply and the plants have grown more controversial, while today's real-time digital economy and sensitive electronics have made blackouts and brown-outs unacceptable.

Power generation is also changing. Wind and solar constitute a significant portion of new power generating capacity. And "decentralized" or onsite photo-voltaic (PV) and wind power generation are also accelerating, so that traditional electricity consumers are becoming also nontraditional suppliers.

Consumption patterns are changing as well – driven first by the plethora of new electronic devices, and now by the anticipated emergence of plug-in electric vehicles. Taken together, these represent a substantial and complex new load on the electrical grid.

And changes across the marketplace and the technology landscape are forcing changes in the business models of utilities and both intrastate and interstate regulation – with important consequences for the grid. According to North American Electric Reliability Corporation (NERC), while the U.S. currently has ample reserve generating capacity, four new regulations promulgated by the U.S. EPA will eventually subtract 45-75 GW of coal, oil, and natural-gas fired generating capacity. If the loss occurs before new resources are brought online, grid reliability could be threatened.

So, why have a Smart Grid? In a nutshell, its advocates maintain that the complex of new demands, new supplies, shifting goals, use patterns, and technologies cannot be managed reliably and economically without one.

Costs and Benefits

Modernizing our electric infrastructure and implementing a smart grid is going to be expensive. A research projection by Credit Suisse pegs the total investment at $1.5 trillion. The key, therefore, is to prove to utilities and regulators that the real value to consumers exceeds the initial costs, as the benefits of having a 21st century infrastructure that supports a digital economy and greater energy security are priceless.

As an example, Baltimore Gas & Electric (BG&E) estimates its cost for smart grid development and deployment to be $482 million through years 2009–2014. But – that investment is expected to return to the utility over $2 billion in economic benefits over 20 years.

While some costs will be passed on to customers, BG&E expects ratepayers to reap reductions in monthly electrical costs by participating in dynamic pricing, peak shifting, and demand response. The technologies of the smart grid need ultimately to be paired with changes in customer behavior, but changes that will have a knowable payback. Savings would come from avoiding high-priced emergency power purchases, construction of new generating plants, and construction of more distribution capacity and operating the entire system more efficiently. Altogether, BG&E projects electric bill savings for residential customers from a low of $0.21 per month in 2010 to a peak of $10.12 per month in 2016, then tailing off to $9.01 per month in 2017.

For commercial buildings, the analysis of 10 PG&E smart grid projects involving automated demand response yielded an average payback of 2.25 years.

Renewable Energy

To make renewables work on a large scale, the grid needs to accommodate the intermittence of solar and wind power to the grid via smart technologies. The problems are obvious. Sunlight is sometimes blocked by clouds and generally peaks earlier than peak loads. Wind is variable and generally peaks at night. But the grid is designed for constancy and consistency. How, then, can it integrate solar and wind generating stations?

First, there are new tools coming on line. Massive battery banks and super capacitors can “bridge” short term gaps in output and smooth out spikes and other distortions of electricity wave forms. Kinetic storage such as compressed air and pumped hydro can store wind and PV power until it is needed. And sophisticated modeling, forecasting, and control of wind/solar generators can help grid operators anticipate and work around interruptions and spikes that last beyond storage capacities.

Microgrids

The Electric Power Research Institute (EPRI), a premier utility funded non-profit research organization that is among the most respected in electrical power research, is looking at another way that buildings can integrate with the Smart Grid: microgrids.

Microgrids are decentralized power generation sites that include photo-voltaic (PV) arrays installed on buildings, small-scale wind turbines, diesel gensets, and gas-fueled microturbines. Such technologies could substantially reduce the need for new power plants. But the challenges are significant - one of the major challenges with integration of distributed energy resources being the management of those diverse resources, tens of thousands or even millions of end points, in the same manner as conventional generation.

One approach being explored is to manage these resources as a “virtual power plant.” Using smart grid sensors and controls, distributed sources are connected to a central operator who manages the aggregated power in the same manner as a conventional power plant.

However, numerous challenges still exist in the creation of a virtual power plant, and the EPRI Smart Grid Demonstration project is focused on leveraging existing and emerging technologies and standards to advance the integration and interoperability of distributed energy resources and associated systems. EPRI’s microgrid concept integrates four smart grid resources: distributed generation, renewable generation, storage, and demand response. For example, if a transformer is lost, the wind dies, or a cloud passes by, the operator can dispatch power from somewhere else.

Microgrids offer a valuable glimpse into the complexity of the energy of the future. But as complex will be management of the consumption end of the equation.

As the U.S. energy infrastructure is changing in many ways and all at once, energy efficiency, energy sources and the smart grid are converging to point a path to a very different energy and electricity future. The smart grid needs to assume a central place in the energy agenda for two reasons. First, the U.S. simply needs to be more efficient with energy, and, second, the technologies developed with the Internet make it possible, at least in principle, to manage electric power — as it is sometimes said, from turbine to toaster.

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