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# Report on Carnegie Mellon's Smart Grid Conference March 2010

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## Carnegie Mellon's Smart Grid

Grey skies. Snow melted. March in Pittsburgh. One speaker came from Hawaii. That' s real tribute. The Sixth Annual Carnegie Mellon Conference on the Electricity Industry featured two days of smart grid, and in truth, I feared being buried in smart grid hype, or discovering that the Federal government had found new ways to distribute my money with abandon, following J.M. Keynes admonition that it was better, in hard times, to pay a worker to dig a hole and then fill it up again than to stay home unemployed. Now we take you to Pittsburgh.

The National Academy of Engineering picked the electricity system as the greatest engineering achievement of the twentieth century. But, as Lester Lave, the business school co-chair of the conference pointed out, by the 1970s, the industry faced increasing costs and blackouts. Proposals to fix the industry, now, include pure technology solutions, the transmission highway and renewable portfolio standards. Good engineering, however, means not only good technology but also good business.

The goals for an industry improvement program should include inexpensive electricity ( with costs internalized), sustainability (meaning a 30-50 year time horizon for decisions) and elimination of distortions caused by unwarranted subsidies and bad pricing? Cost effective solutions include energy efficiency ( which has the potential to eliminate the need for new generation through 2030), life style changes and dynamic pricing.

Take pricing. Customers might pay 10¢ per kWh for electricity that costs anywhere from 7¢ to $3.00 per kWh. Without price signals to customers, demand gets peakier. Price requires a capacity charge. Dynamic pricing reflects costs. Time of use pricing does not provide a good approximation of costs. Real time prices reflect costs, but are hard to explain and customers resist them. The utility could charge actual prices with a rebate for non-use, or just control customer load.

Customers don't know about electricity. Electricity suppliers don't know what customers want to know. Some put their hope in advanced meter infrastructure (AMI), meaning smart meters. But, why waste money on meters for small customers. Only 40% will produce a payback on smart meters. Don't spend a dollar to save a penny.

To make real time pricing (RTP) work, customers need to understand RTP, to trust the provider, to understand that some will lose, and to have the ability to access day-ahead prices.To implement, the provider has to get the public service commission and consumer advocate on board, experiment first in small groups, and do it cost effectively.

Sobering reminder: the set back thermostat doesn't work because people don't know how to use it. We don't know what the really time price really is, either.

(Do you get the feeling that something imperfect, simple and explicable trumps the perfect pricing system?)

What about the billions of dollars going into smart grid grants? Joseph Paladino of the Department of Energy (DOE) pointed to a DOE manual snappily entitled "Measuring Progress and Benefits of ARRA Smart Grid Programs." The DOE wants feedback. "We don't know the benefits of smart grid and we really want to know." The law requires the DOE to get the money out the door within one year and the grantee to spend it within five years. This is economic stimulus money, after all. The Council of Economic Advisors wanted the grantee to do rigorous studies of consumer behavior, to determine the role of dynamic pricing. The DOE had no legal basis to require that, so it made the proposal elective, and ten utilities did bite.

The information technology industry moves into the power industry, The operator will make more informed decisions, which leads to greater efficiency, reliability and reduced greenhouse gas (GHG) emissions. That's the hope. Renewables require a more flexible grid, too.

No consensus on benefits exists, due to a lack of demonstrated results. Can peak load be reduced, what is the value of distributed monitoring and control ( how much efficiency gained)? Yet, isn't digitalization inevitable? Smart grid means digitalization.

DOE wants to determine the impact of building the smart grid. It does not know how long it will take to measure results. It does not want to do cost benefit analysis. That would be the task of the state regulators who will have to decide whether to roll out large scale smart grids.

(Yes, it does sound as if Congress decided to shovel out the money in a hurry, but it also looks as if the DOE will get real and useful information from the grants, which could provide practical guidance to potential smart grid employers.)

Much of the benefit of smart grid depends on convincing consumers to change their habits, to use less at peak periods. Ahmad Faruqui of Brattle group has conducted many studies of consumer reaction to price. Recently, several conversions to smart meters blew up. Customer blamed the new meters for higher bills. In Bakersfield, California, some customers who protested did not have the smart meters with the new rates. This is a public relations challenge.

What about the previous tests? The old pilot projects, by and large, permitted self selection, had no controls and did not qualify as real experiments. Time of use pricing never caught on. Restructuring restructured supply, not demand, a formula for disaster.

An analysis for the Federal Energy Regulatory Commission (FERC) showed that demand response (from dynamic pricing) could eliminate 20% of demand at peak, but utilities could achieve at least 25% of the benefits without smart meters.

Worldwide tests over the past 10 years show reductions in peak demand often 10-30% . Residential customers respond, too. Price elasticity of demand seems to range at -0.07 to -0.13. Furthermore, customer response persists.

Customers respond to a rebate for non-use at peak, too. We are not sure how they will respond to metering. We do not know what works best, do not understand customer preferences, but do know that customers do not like price volatility. How to get the customer to choose the program? Maybe make the best option the default option.

(Consider all the studies, the statistical work, the knowledge that price seems to affect demand-- not a surprise-- so why all the uncertainty about how customers will act? This industry, perhaps, does not know its own customers.)

How do utilities look at smart grid programs?

Chris Bennett of Florida P&L initiated the smart grid project before the handouts began. The FP&L program focuses on operations, rather than pricing. It will monitor the grid, watch transformer performance, reroute the grid in case of storms, allow the company to respond more quickly. The program could increase efficiency, reliability and customer satisfaction. A dynamic pricing program for customers, probably, would not fit into the Florida regulatory model, at present.

FP&L is a fully regulated, vertically integrated utility. Pepco, on the other hand, is a distribution and transmission utility, with a different view. Stephen Sunderkauf, of Pepco, emphased metering and two way communications to work with consumers. The utility was concerned about the high price of electricity in deregulated markets. Thanks to the decoupling of revenues from volume, Pepco can line up with the interests of customers, and help them to reduce their energy consumption and their electric bills.

Let's go to the technical discussions. They will all end up on the internet, so get the details there, complete with equations. A digest follows:

A sustainable electricity system requires attention to short and long term efficiency. (Does the day ahead market do that?)

Smart grid could invade privacy. The load signature could reveal information about activities within the customer's premises.

Who owns the information collected by the smart grid?

We don't know the value proposition for smart grid, what to market. Maybe we will have to use cognitive psychology to find out, to learn from the consumer.

Purpose of smart grid: to make the customer better off, which could even mean, more pronounced peaks and more consumption of electricity. (Did you think of that?)

Smart grid should accommodate all types of generation, allow active participation of customers. Renewables create difficulties and the network has to move to probabilistic models to accommodate them.

The network has to learn to deal with high impact events that have a low probability of occurring. ( Does that sound like a discussion of the recently discovered failings of risk management at financial houses?)

An information technology (IT) approach, alone, will not protect the system, which becomes more vulnerable as it becomes more interconnected. Grid reliability standards should assume that control measures will fail. They should protect against non-malicious errors. Worry about common devices as well as people. (Everything in an office is connected to the printer. He who captures the printer captures the office.)

At the (large) customer level, put in devices that schedule production, usage, and storage. The devices relay the scheduled consumption of electricity to the grid to help improve forecasts of consumption. They could jointly schedule with the grid to maximize rewards. They could support energy conservation and optimization at the customer level. ( Could these robotic energy managers, also, bargain with the gird on an iterative basis? When faced with a higher than desired price, could the device tell the grid that the customer will take less electricity, thereby creating a two sided electricity market.)

Load forecasting errors may reach 3-5% in the day ahead market. On a "non-trivial" number of days, though, errors are far larger. Geomagnetic storms , for instance, can affect loop flows, as can flows scheduled by grid operators elsewhere. The grid needs a flow model so that operators know what to expect.

Two breaks in the technical program.

Lester Lave, said: lay off these analogies that compare electricity to telecommunications. Nobody uses electricity.They just plug in devices. What will anybody do differently? The electric company does not provide applications.

Jay Apt, ex-astronaut, who runs the electricity center at Carnegie Mellon, examined the integration of renewables, which now provide 9% of electricity (6% of which is hydro). Droughts cause variability in hydro production. Wind droughts affect wind production. Capacity factor for wind is about 25%. Wind could fail for days on end, so the grid has to back it up with other generation. Calculations of GHG avoided by wind should take into account the emissions of generators that the grid has to ramp up and down to replace the lost wind. Other problem, the correlation of wind output to load is -0.9, meaning that most wind does not blow when we need it, but does blow when the price is lowest. Solar suffers from fluctuations as well, with a capacity factor of 19%. Transmission costs plenty, so it may be more economical to use poor quality renewables close to the load than high quality but distant renewables. What's needed for renewables? Better predictions of variability, a strategy to reduce variability at the point of production, power plant dispatch based on uncertainty, improved monitoring, thermal storage, microgrids that can react to variability and new standards for frequency control. (Did any of that get written into renewable standards?)

The problems associated with wind led to a plethora of strategies. Pay attention to the cost of ramping up back up power. Eliminate network constraints. Consider electricity as a type of perishable inventory and use operations research to determine a strategy for inventory and storage. Integrate demand side management into the calculations, in order to minimize back up power needs. Combining wind with natural gas turbines is not good enough, because the gas turbine can't activate fast enough, so a storage battery should be added to the team, and charge up the battery when demand is low.

Security came up. It always does. Smart grid couples a traditional energy system with computer science. It requires coordination. Can the middleman be trusted? Avenues of attack include impersonation of devices and a coalition of attackers. Think of a foreign country trying to bring down the grid. It takes only $500 of equipment to take control of advanced metering infrastructure (AMI). Designers have to build in security, not add it on later. Patches can aid the attacker, who can reverse engineer the security fix. A slammer worm shut down the Davis-Besse nuclear unit in 2003, for five hours. A site on the internet already offers a tutorial on hacking into the smart grid. And, back to privacy. The utility can know when you are at home, how many are at home, doing what. Imagine the first subpoena of this information. Bottom line: there still is not much coordination with privacy and security researchers. One vendor said, "This is critical infrastructure. We don't want you to test it." ( Will consumers, who don't have legal redress when the lights go out, have legal redress for privacy and security lapses?)

Modern portfolio theory (MPT) showed up, too. It usually applies to stocks and bonds. It says that the portfolio manager can put together a portfolio of securities that takes into account the riskiness of each security and the potential return from each, in such a way that the portfolio provides the optimal combination of risk and return. Why not apply

MPT to a portfolio of sources of power, and diversify those sources in a way that provides the best combination of risk and return? In the old, regulated days, the utilities did that, sort of, by avoiding over-reliance on one fuel or one power station. ( Nowadays, in our efficient markets, they drop all the risk on the unsuspecting customer.)

Marija Ilic, of the engineering part of the team, commented on the damage caused when some aspect of the grid fails, thereby causing loop flows between regions, which, in turn, cause more havoc, and nobody is in charge of them. Without coordination between regions, the tie line might manage to carry, let's say, 1 MW. With coordination, maybe the line could carry 30 MW. With a phase angle regulator in place and coordination, maybe it can handle 80 MW. What's the solution, now? Build a new transmission line. The smart grid is about coordination. Maybe the system should work to coordinate exchanges rather than build more lines. Maybe it needs a coordinating entity. (Maybe it needs a for-profit coordinating entity to add some urgency and accountability.)

Have I left something out? Plenty: smart green buildings,a smart grid simulator, models, understanding loop flows, dealing with uncertainty, non-intrusive load monitoring, running wind mills for base load, adaptive load management, and more. Read the papers.

My top ideas for implementation:

- The robotic system to gather information at the customer level to furnish to the market. ( I'd like to see the idea pursued to its logical conclusion, a robotic bidding system to bring about real two-sided markets. Computer bidding is common in securities markets, already. Maybe we could learn from what already exists. )

- Apply portfolio theory to the generating mix, in order to reduce risk to customers. ( I'm not thrilled with MPT, but just doing the exercise will help sort through the risks and inform judgement. Maybe the portfolio could be attached to an insurance scheme that helps consumers when the unexpected happens.)

- To improve reliability between regions, put an entity in charge to bring about cooperation as an alternative to building assets. ( Perhaps this requires a profit making insurance type effort. How about selling shares in it to transmission owners to encourage their cooperation?)

The smart grid will create opportunities to better manage the network, to deal with the more probabilistic world of renewables, to provide customers with more choices. But, who is in charge?