Will the US Electric Grid Be Our Undoing?

Posted by Gail the Actuary on December 31, 2008 - 11:54am
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Back in May 2008, I wrote a post on the US Electric Grid. With the Obama administration taking over shortly, I expect there will be more discussion about upgrading the US electric grid, so below the fold is a re-post of the earlier essay.

One obstacle to upgrading the grid not discussed in my earlier post is the issue of the differing costs of electricity around the country, depending on the fuel used to produce the electricity (natural gas tends to produce high-cost electricity; coal and nuclear produce lower cost electricity). As the grid currently operates, the limitations of the grid tend to discourage huge long-distance redistribution of electric power. If the impact of a new electric grid back-bone is to start evening-out electric rates across the country, customers currently in low-cost areas will tend to oppose the change, because their rates may be higher. This could create a significant obstacle to passing legislation to upgrade the grid.

I am not sure whether this will be an issue in practice. With the grid upgrade, areas currently with inadequate local electrical production will more easily be able to import electricity from elsewhere, so their costs may be lower, not considering the cost of the grid upgrade. Rates in areas which are currently low-cost will increase to the extent that customers are charged for the new grid upgrades, but it is not clear that they will increase otherwise. If low-cost utilities are able to sell some base-production that might otherwise go to waste, the grid could theoretically lower costs to even currently low-cost customers.

The real issue at this time might be that with the world's current financial problems, it will be difficult for any organization (US government or local utility) to borrow money to support such a large upgrade. This will leave only a couple of options. One possibility is that the US government could raise taxes to finance such an upgrade. Such an option is likely to be unpopular. Another option would be for utilities to raise rates sufficiently to pay for the upgrade as it is constructed. This also is likely to be unpopular, especially for those customers receiving relatively little benefit from the grid upgrade.

May 2008 Post

Quite a few people believe that if there is a decline in oil production, we can make up much of the difference by increasing our use of electricity--more nuclear, wind, solar voltaic, geothermal or even coal. The problem with this model is that it assumes that our electric grid will be working well enough for this to happen. It seems to me that there is substantial doubt that this will be the case.

From what I have learned in researching this topic, I expect that in the years ahead, we in the United States will have more and more problems with our electric grid. This is likely to result in electrical outages of greater and greater durations.

The primary reason for the likely problems is the fact that in the last few decades, the electric power industry has moved from being a regulated monopoly to an industry following more of a free market, competitive model. With this financing model, electricity is transported over long distances, as electricity is bought and sold by different providers. Furthermore, some of the electricity that is bought and sold is variable in supply, like wind and solar voltaic. A substantial upgrade to the electrical grid is needed to support all of these activities, but our existing financing models make it very difficult to fund such an upgrade.

If frequent electrical outages become common, these problems are likely to spill over into the oil and natural gas sectors. One reason this may happen is because electricity is used to move oil and natural gas through the pipelines. In addition, gas stations use electricity when pumping gasoline, and homeowners often have natural gas water heaters and furnaces with electric ignition. These too are likely to be disrupted by electrical power outages.

Introduction

The whole discussion of electric grids may be a foreign topic for some readers. Because of this, let me start off with a couple of analogies:

1. Sometimes the analogy of water in pipelines is used as being similar to electricity and the electric grid. Transmission lines are like pipes. Voltage is like water pressure that forces electricity over long distances. Amperage is the amount of water flowing through the pipe. Our big challenge is that what we want the pipes to do is constantly changing, because of regional load shifting, peak demand, and intermittent generation. Sometimes we are slamming the system with a large slug of water. At other times, we have a trickle, but we still want an even flow out of the faucet. With these stresses, it is easy for the electrical system to get the equivalent of banging pipes and chattering faucets.

2. When I rented my first apartment in graduate school, I soon discovered it had exactly two 15 amp circuits. If I wanted a window air conditioner, it needed to be a small one, and it needed to be on the opposite circuit from the refrigerator. If I wanted to use an electric iron, I needed to think carefully regarding where I could plug it in, without blowing a fuse. I always needed to be aware of what was running on which circuit, if I wanted to keep the lights on.

The US electric grid is clearly not as bad as the wiring on my first apartment, but there are some similarities. The grid dates from a period not too much after the wiring in my apartment.

The US Electrical Grid in the 1960s

The current electric grid has its origins in the 1960s. One article noted that our current grid dates from the time when Frank Sinatra was in his prime, before a man walked on the moon, and before cell phones were invented.

At that time, electric utilities were pretty much local operations. Each utility was vertically integrated--that is, handled the entire supply chain of electricity production and distribution. The transmission system was set up so as to optimally serve its local area. There were some transmission lines to nearby utilities for use in emergencies, but the transmission grid was mostly set up to serve local customers.

Utilities were generally regulated as monopolies, and allowed to pass costs on to customers. One of the utility's costs was the upkeep of transmission lines. Since these were necessary for operation, these were kept in good repair.

This model seemed to work for the electric system of the day. The most important law at that time was the Public Utility Holding Company Act (PUHCA), passed in 1935. Under PUCHA, electricity was a regulated industry, covering both generation and transmission.

Partial Deregulation of the Electric Industry

Starting in the late 1970s, deregulation became the fashion for many industries, including trucking, airlines, natural gas, telecommunications, banking, and health care. The law that opened the door to partial electricity deregulation was the Public Utilities Regulatory Policy Act of 1980 (PURPA), passed when Jimmy Carter was president. The law was intended to encourage efficiency in electricity production and to help the "little guy".

Under PURPA, a utility was forced to purchase electricity from any "qualified" producer. To qualify, a system either had to produce electricity using an alternative source such as wind or solar, or had to meet a very modest efficiency standard. Natural gas production could qualify under the efficiency standard.

In the years after 1980, there was a move toward free market economics and capitalism. Under the new model, the purpose of a utility was to make money for its stockholders. Growth was an important objective. In some states utilities were forced to divest of their assets, with the idea that the smaller pieces would encourage competition. Power plants were bought and sold, and the new buyers were not necessarily in the utility business. Some buyers were hedge funds.

Electricity became a commodity like any other commodity, with widespread trading in electricity contracts, futures, and other derivatives. The financing model even included securitization, using bonds backed by future revenues related to planned recovery of stranded costs. At one point, marketing of electrical energy became a huge source of revenue, apart from the actual generation of the revenue.

After a few years of trying to the new system, some of the problems of the new approach became clear. In 2001, Enron's manipulations of market prices became apparent, and in December 2001, it filed for bankruptcy. There were also a number of other new entrants into the electricity business that also failed, including Mirrant Corporation and Allegheny Energy.

Since 2001, there has been some back-pedaling at the state level on deregulation, with a number of states suspending deregulation. At the federal level, the push has been in the direction of competition, but with more federal oversight. The Energy Policy Act of 2005 repealed PUHCA (the 1935 act which enabled local monopolies), but gave the Federal Energy Regulatory Commission (FERC) a bigger role in the oversight of power transmission. The Energy Policy Act of 2005 also gives FERC oversight of an industry self-regulatory organization called North American Electric Reliability Council (NERC).

Energy Independence and Security Act of 2007 (EISA) makes yet another stab at helping the grid. Title XIII of ESIA establishes a national policy for grid modernization, creates new federal committees, defines their roles and responsibilities, addresses accountability and provides incentives for stakeholders to invest. The act only "authorizes" these activities, but does not actually provide funding. As far as I know, the funding has not yet happened.

With these changes, the industry continues to be much more fragmented than it was prior to deregulation. There is some state regulation, but the model of financial profitability and growth continues to play a big role. There is still widespread trading of electricity across long distances and use of derivatives and other financial instruments. The federal government has taken some steps toward more direct involvement, but it is difficult to do very much very quickly in such a fragmented industry.

What happens to transmission under deregulation?

When a utility's primary role is taking care of its own customers, there is a strong incentive to carefully maintain its transmission and distribution system. Once the system is divided into many competing entities, many of whom do not have financial ownership of the transmission system, the situation changes significantly. Some of the impacts include:

1. Declining investment. There is less incentive to maintain transmission lines, since under a fractured system, no one has real responsibility for the lines. Also, profits are higher if equipment is allowed to run until it fails, rather than replacing parts as they approach the ends of their useful lives.

2. Overuse of lines between systems. Prior to deregulation, transmission lines between utilities were designed for use primarily in emergencies. Once widespread trading of electricity began, lines between utilities are put into much heavier use than they had been designed to handle.

3. More rapid deterioration. After deregulation, there is much more cycling on and off of power plants and the structures involved in transmission, to maximize profits by selling electrical power from the plant that can produce it most cheaply. This results in metal parts being heated and cooled repeatedly, causing the metal parts to deteriorate more quickly than they normally would.

4. Unplanned additions to grid. Wind and solar are added to the grid, with the expectation that the grid will accommodate them. "Merchant" (investor owned) natural gas power plants are also added to the grid, sometimes without adequate consideration as to whether sufficient grid capacity exists to accommodate the additional production.

5. Difficulty in assigning costs back. Since the industry is more fragmented, if any transmission lines are added, the cost must somehow be allocated back to the many participants who will benefit. Ultimately, the cost must be paid by a consumer. These consumer rates may in fact be regulated, so it may be difficult to recover the additional cost.

6. Increased line congestion. There is a need for more long distance transmission lines, because of all of the energy trading. There is a great deal of NIMBYism, so approval for placement of new lines is very difficult to obtain. The result is fewer transmission lines than would be preferred, resulting in more and more line congestion.

7. No overall plan. There is a need for an overall plan for an improved system, but with so many players, and so much difficulty in assigning costs to players, very little happens.

8. Little incentive to add generating capacity. As long as there is a possibility of purchasing power elsewhere, there is little incentive to add productive capacity. Profits will be maximized by keeping the system running at as close to capacity as possible, whether or not this causes occasional blackouts.

What do industry leaders say about the U. S. Electric Grid?

It is hard to find anyone who has anything very complimentary to say about the US grid. When Bill Richardson was energy secretary during the Clinton administration, he called the grid a **third-world grid**.

The Report Card for America's Infrastructure, prepared by the American Society of Civil Engineers, gives the US Electric Grid a **rating of D**. Its summary says the following:

> The U.S. power transmission system is in urgent need of modernization. Growth in electricity demand and investment in new power plants has not been matched by investment in new transmission facilities. Maintenance expenditures have decreased 1% per year since 1992. Existing transmission facilities were not designed for the current level of demand, resulting in an increased number of "bottlenecks," which increase costs to consumers and elevate the risk of blackouts.

An article from EnergyBiz by Edwin D. Hill, president of the International Brotherhood of Electrical Workers, says:

> The average age of power transformers in service is 40 years, which also happens to be the average lifespan of this equipment. Combine the crying need for maintenance with a shrinking workforce, and we may find that the 2005 blackout that affected parts of Canada and the northeastern United States might have been a dress rehearsal for what's to come. Deregulation and restructuring of the industry created downward pressure on recruitment, training and maintenance, and the bill is now coming due.

Federal Energy Regulatory Commission (FERC) chairman Joseph Kelliher is quoted as saying:

> The U.S. transmission system has suffered from underinvestment for a sustained period. In 2005, the expansion of the interstate transmission grid in terms of circuit miles was only 0.5 percent. At the same time, congestion has been rising steadily since 1998.
>
> Transmission underinvestment is a national problem. We need a national solution. Pricing reform is an important part of the solution to this problem.

Summary of Where We Are Now

A this point, we have a grid that was designed many years ago. Many of the grid's components are near the end of their normal life spans. There is a process for getting new segments added to the grid, but it doesn't work very well. As a result, growth in transmission infrastructure tends to lag behind new additions to generating power.

One of the problems is getting permits for the siting of a new segment, when it has been approved. This can take years if local residents are opposed to additional lines in the area. One estimate is that actually getting a new transmission line installed can take up to 10 years.

Another issue is dividing up the costs among the various entities that would benefit. In some cases, there will be losers as well as winners--for example, a new line may be detrimental to a power plant that would be the low cost producer in the area, but because of the new line, a different plant from a distance can better compete. There may be several entities that benefit. There may be differences in the abilities of these organizations to charge their costs back to the ultimate customers.

There is of course the issue of obtaining funding for a new project, especially one with a very uncertain time frame. Costs relating to grid construction are increasing quite rapidly, for several reasons: Grid construction uses a lot of metals whose cost has been rising recently; China is rapidly building its grid, competing for available transformers and other components; and many of the materials are imported, and are affected by the declining dollar. In addition to the higher cost, there can also be delays in getting equipment, because of the competition from China and other buyers for available equipment.

The grid is now being used extensively for long distance transportation of electricity and for switching among providers so as to obtain electricity at the lowest cost. The grid was never designed for these uses, so it is stressed by them. One of the results is increasing congestion. One particular area of concern is the "Eastern Interconnection".

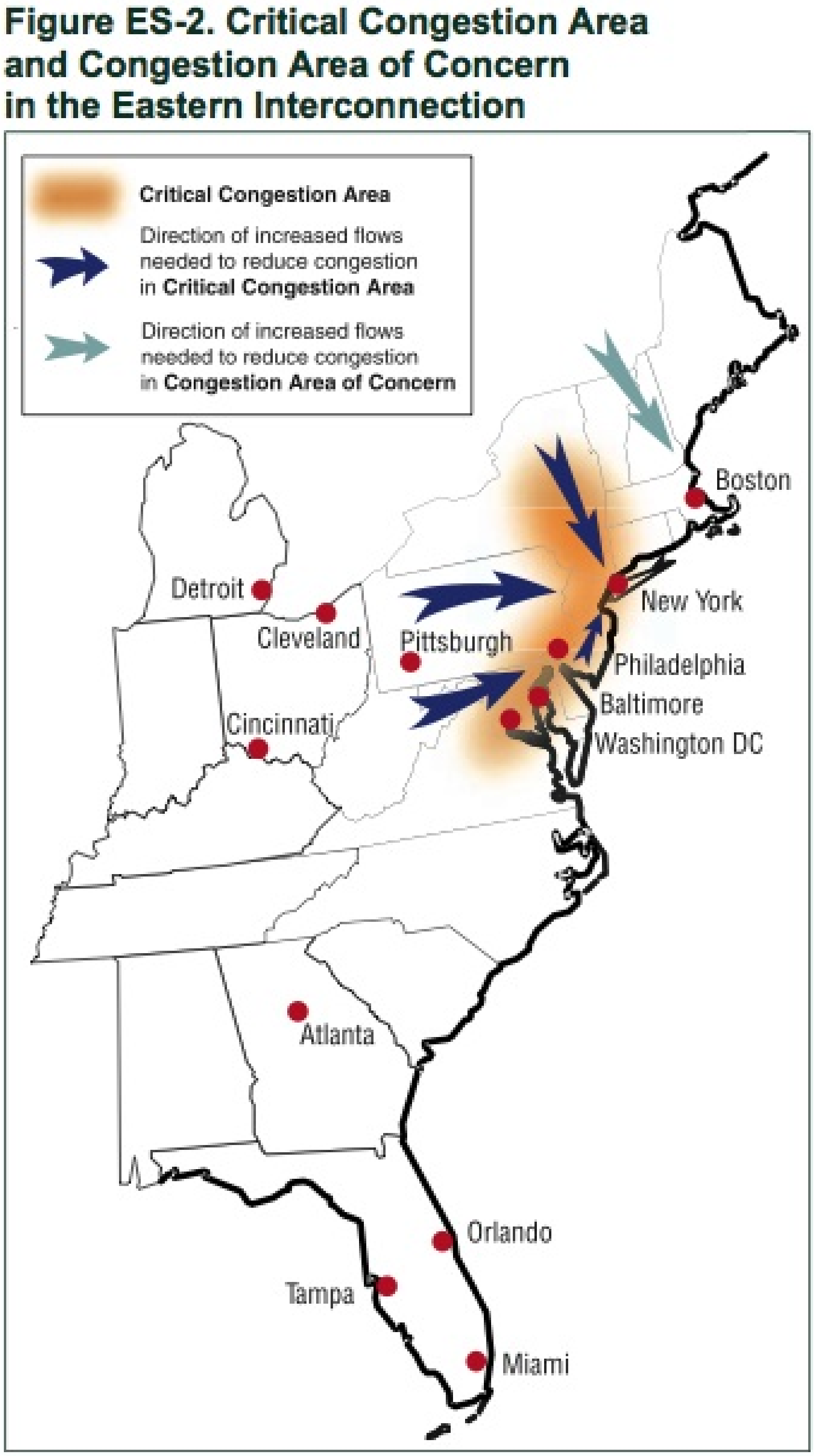

Figure 1. Figure from [Department of Energy 2006 Electricity Congestion Study](#).

The extent to which congestion has been rising in the Eastern Interconnection is shown in Figure 2.

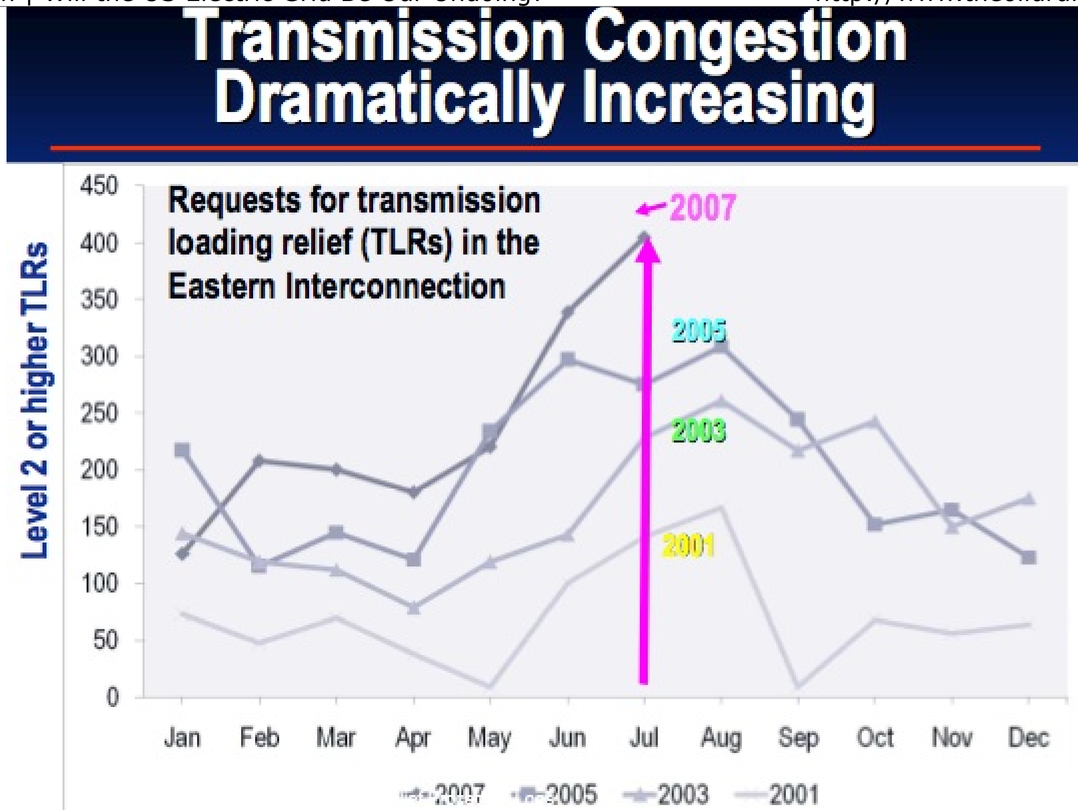

Figure 2. Slide from [presentation]() by David Owens a 2008 EIA Conference.

While I have not shown a graph, another area with excessive congestion is Southern California. Changes to the grid structure are needed to relieve stress in this area as well.

One factor that affects line congestion is the relative cost of producing electricity for different types of fuels. The greater the differential in costs (usually natural gas higher than coal and nuclear), the more the financial incentive there is to import lower cost electricity from a distance. Natural gas prices have recently been rising. If this continues, this will put further pressure on utilities to import electricity from a distance created using coal or nuclear, rather than using locally produced electricity from natural gas.

Until now, additional wind capacity has simply piggy-backed on the general capacity of the grid. According to Stow Walker of Cambridge Energy Research Associates, spare capacity is now depleted, and new transmission capacity will need to be added to accommodate more wind energy. Even with the existing amount of wind energy (only about 9,339/405,582 = 2% of Texas's total electricity, based on EIA production data for 2007), there have been reports of near rolling-blackouts in Texas, when the amount of wind energy suddenly dropped.

In Figure 3, I list states that are importers and exporters of electricity in 2006, based on EIA data. California and many of the Eastern states are big importers. Big exporters include coal producing states like Wyoming and West Virginia, and several states with large nuclear facilities. The percentages of imports and exports shown on Figure 3 are for the full year. It is likely that during peak periods, imports and exports will be much higher percentages than the amounts shown.

Analysis of EIA State Electricity Profile Data for 2006

Electricity Importers

State	Shortfall/ use
D. C.	-99.4%
Idaho	-46.9%
Delaware	-43.9%
Virginia	-38.2%
South Dakota	-36.0%
New Jersey	-31.2%
Rhode Island	-30.9%
Maryland	-30.0%
Minnesota	-28.0%
Massachusetts	-26.3%
California	-25.6%
Wisconsin	-20.3%
Tennessee	-18.4%
Nevada	-16.8%
Florida	-11.5%
Mississippi	-11.1%
North Carolina	-10.8%
New York	-9.7%
Ohio	-8.5%
Colorado	-8.0%

Electricity Exporters

State	Excess/ use
Vermont	10.4%
South Carolina	10.8%
Indiana	11.5%
Washington	14.9%
Oklahoma	16.1%
Illinois	22.0%
Maine	23.6%
Arizona	28.7%
Pennsylvania	35.2%
Alabama	40.3%
Utah	41.3%
New Mexico	57.0%
New Hampshire	79.6%
Montana	84.6%
North Dakota	147.9%
West Virginia	162.1%
Wyoming	174.2%

Electricity Imports	-Megawatt Hrs
California	-67,216,369
Virginia	-40,748,568
Florida	-26,199,754
New Jersey	-24,876,297
Tennessee	-19,141,739
Maryland	-18,971,190
Minnesota	-18,702,852
Massachusetts	-14,680,990
Wisconsin	-14,167,663
New York	-13,790,088
North Carolina	-13,645,656
Ohio	-13,091,272
D.C.	-11,322,869
Idaho	-10,675,785
Georgia	-10,228,174

Electricity Exports-	Megawatt Hrs
West Virginia	52,391,837
Pennsylvania	51,409,205
Alabama	36,533,305
Illinois	31,289,717
Wyoming	26,044,256
Arizona	21,000,649
Texas	18,952,133
North Dakota	16,636,575
Washington	12,660,610
New Mexico	12,211,252
Indiana	12,151,510
Montana	11,685,408
Utah	10,889,916

Note: Amounts shown are not exact. Production is greater then use because of line loss. Calculations assume equal percentage of line loss for all states.

Figure 3. Based on EIA Data.

Federal legislation was passed in 2005 and 2007 which should help the grid situation a little, but it still leaves the many individual operating entities to share responsibilities and costs. The basic model is still one of competition, with governmental and industry organizations trying to get the various entities to work together for the common good.

What Changes Are Needed to the Grid?

We would have a very large task if we simply wanted to fix the grid to do what it was originally planned to do, since many of the grid's elements are close to the ends of their useful lives.

Unfortunately, nearly everyone who looks at the situation believes that a major upgrade to the grid is needed, rather than just patching the current system. From my reading, I have identified three basic changes that people believe to be necessary, over and above just getting the old system into better operating order. These are

1. Extra High Voltage Backbone. FERC commissioner Suedeen Kelly has been quoted as saying:

> In order to truly capture not only the benefits of competition in generation but also to facilitate increased use of renewable resources, I am convinced that we will need not just to upgrade our electric grid but also to reconfigure it. We need a true nationwide transmission version of our interstate highway system; a grid of extra-high voltage backbone transmission lines reaching out to remote resources and overlaying, reinforcing, and tying together the existing grid in each interconnection to an extent never before seen. To get to that end state, we must have cost allocation provisions in place that can accommodate such wide ranging benefits.

2. Analog to Digital Grid. If we are going to enable energy efficiency, many believe we need to move from an analog to a digital grid. James Rogers, CEO of Duke Energy, says :

> If you're going to enable energy efficiency, you have to move from an analog to a digital grid with new transformers and new meters capable of two-way communication.

The **Smart grid** concept is very closely related to the digital grid. At the Green Intelligent Buildings Conference, keynote speaker Paul Ehrlich said:

> We need to find ways to make the grid smarter, to make buildings smarter, and to have these smarts communicate with each other.

3. Real-time Transmission Monitoring System. With such a system, it would be possible to react more quickly to sudden shifts in power needs or power availability, and prevent cascading blackouts. Adopting such a system would not be simple. A 2006 study by FERC lists these steps:

> • Define What a Real-Time Monitoring System is, What it Should Accomplish, and How to Accomplish it
> • Evaluate Existing Real-Time Monitoring Technologies and their Limitations
> • Identify Required Communications and Related Security and Operating Issues
> • Define Data Requirements
> • Identify Promising Emerging Technologies
> • Decide what Data Should be Shared, with Whom, and When
> • Decide Who Should Operate, Use, and Maintain the System
> • Identify Potential Participants Involved in Establishing a Real-Time Monitoring System
> • Consider Cost and Funding Issues

How do we get from where we are now, to where we need to be, in a reasonable amount of time?

I am having a very difficult time seeing how this can be done. There are just too many entities and too many funding issues to make a transition from a neglected old system to a much-improved new system in a reasonable length of time. Our current economic model seeks growth and the maximization of profits. This economic model does not facilitate large groups of entities working together for the common good.

The transformation seems unlikely to succeed, if for no other reason than the fact that the cost of the new system is likely to be very high. Electric rates will already be increasing because of higher natural gas prices and the cost of building additional nuclear power. Adding the costs for a substantial upgrade to the transmission system at the same time would be very significant burden for the consumer. If we are dealing with peak oil at the same time, this will add an additional stress. It is difficult to believe that politicians and state regulators will allow such large costs to be passed back to consumers.

If anything would work to produce the desired result, it would seem to be something that approaches nationalization of the electric supply industry. If this were done, the problem of conflicting objectives could be greatly reduced. I have a hard time envisioning current leaders accepting such a radical approach, however.

What will happen if we just continue business as usual?

It seems to me that as more and more of transmission infrastructure exceeds its normal life expectancy, there will be more and more blackouts. Areas where there is high congestion, such as the Eastern Interconnection and Southern California, would seem to be particularly at risk. It seems like some of these blackouts could be very long (two weeks?).

With the current system, it takes longer to get new transmission lines in place than to build new natural gas or wind generating capacity. Because of this, we are gradually increasing the amount of constriction in the grid. We may have to forgo adding new generating capacity, particularly of wind, until sufficient additional transmission lines can be added.

Nuclear plants are big enough that they often can supply power to a fairly large area. If new nuclear plants are added, it may be difficult to add enough transmission lines to use the power they generate optimally. We may find ourselves able to use only part of the power the new plants are capable of generating because of transmission difficulties.

How about the longer-term outcome?

Longer term, if we cannot get the problem fixed, it seems likely that we will revert back to something closer to what we had in the 1960s, with local electric utilities serving an immediate area. There may still be some long-distance sale of electricity, but less than today, if the grid cannot support it. If some areas do not have enough locally-generated power, they may be forced to have planned blackouts, perhaps for several hours a day.

There would almost certainly be indirect impacts, if some areas of the country are subject to periodic electric outages. As mentioned at the beginning of this article, there may be impacts on oil and natural gas use, either because of problems with pipelines, or because of problems with people's equipment that uses natural gas, but has electric ignition.

It is hard to know where the impact of intermittent electricity would end. For example, electric power plants currently get their fuel from very long distances. Georgia imports coal from Wyoming to run its power plants. Most uranium is imported from overseas. It is possible that some of these supply lines could be interrupted as an indirect result of the electricity disruptions, further disrupting electric power. The interconnections of electricity with petroleum, natural gas, and other operations could be the topic of another post.

If we cannot get the electrical grid upgraded, it seems like we will need to downgrade our expectations for applications such as electrified rail and plug-in electric hybrid cars. These will work much less well if there are frequent electric outages in much of the country. We may also need to downgrade our expectation for newer renewables because of the intermittent nature of their output, and the inability of local grids to handle this type of input. Efforts at higher efficiency may also be hindered, if we are unable to make the grid "smart".

References

I link to a number of studies and presentations in the post. In addition, I should also mention:

Electricity: 30 Years of Industry Change Presentation by David K. Owens, Executive Vice President, Edison Electric Institute, April 7, 2008.

Light's Out: The Electricity Crisis, the Global Economy, and What It Means to You by Jason Makanski, published by John Wiley in 2007.

Lines Lacking to Transmit Wind Energy USA Today, February 26, 2008.

State Almost Saw Rolling Blackouts Dallas Morning News, February 28, 2008.

2007 Long-term Reliability Assessment North American Electric Reliability Corporation.

Previous Electricity Article

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