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# Ensuring the Resilience of the U.S. Electrical Grid

## *Part IV: Key Investment Areas and Next Steps*

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December 2012

### INTRODUCTION

It has been widely observed across many aspects of life that, "knowledge is power," and this certainly holds true in the case of knowing what is happening and why across the many pieces that comprise the electrical power grid. Specifically, because electricity from the grid cannot be stored and must instead be continuously generated and transmitted and then instantly consumed, the power of knowing in real-time the precise demand, actual supply flows, and any anomalous energy losses throughout the system is even more important than in many other arenas.

Indeed, many of the most important of the ongoing grid modernization and infrastructure improvements currently underway are aimed at this very issue – the development of a so-called "smart grid" that can (among other facets) better track power usage, measure it against traditional usage patterns, and identify anomalies.

In particular, the increasing application of advanced analysis tools coupled with wireless communications embedded within many devices and enabling distributed real-time monitoring is increasing efficiency by improving our ability to find and fix problems earlier than was previously possible. This includes better targeting of recovery efforts when anomalies do occur.

This ability to conduct real-time monitoring of energy generation, transmission and delivery, as well as other whole-system performance indicators, is especially relevant to the issue of effective energy management. By avoiding wasteful systemic failures the time required to intervene if and as warranted is reduced.

In other words, without the right monitoring devices in place, we won't know there is a problem until it is too late to either avert or at least minimize an adverse event. This lack of situational awareness has effectively increased the likelihood of facing preventable disruptions, such as energy being wasted by flowing unregulated out of the system at a broken substation linkage, or perhaps overloading and eventually crippling a critical node or power line.

As it turns out, however, knowledge may translate to power, but not all knowledge is created equal, and some means of acquiring it are not as efficient as others. For instance, in the rush to develop and deploy residential-use "smart readers" over the past few years, there was a lack of focus on developing specific industry standards and interoperable systems that would have saved money in the long run by being standardized, interoperable and/or interchangeable. Unfortunately, the rollout of non-standardized technology solutions reduced the ability to achieve wide-scale interoperability, ultimately costing users money as potential savings are either forfeited or achieved only by retrofitting or replacing these early systems.

**Ensuring the Resilience of the U.S. Electrical Grid**


Part I: Fixing It Before It Breaks

Part II: Risks to the Electrical Power Grid are Persistent …and Growing

Part III: Requirements for a More Resilient System

★ **Part IV: Key Investment Areas and Next Steps**



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In the final analysis, however, the failure to develop better standards and more interoperable systems before moving ahead with widespread deployment should not detract from the clear case for continuing to move towards a knowledge-centric power grid. Rather, the case for moving ahead with the smart grid and related improvements is a classic case of costs versus benefits. Although the true magnitude of both the costs and the benefits are hard to fully predict and are playing out on such a massive scale that even small deviations can matter significantly, some of the relevant considerations include:

- Plans to modernize our vast power grid are estimated to cost $1.5 trillion over 20 years, or some $75 billion per year for the next 2 decades.[1]

- Each year American households and businesses lose an estimated $20 billion per year in direct losses of electric power, and up to $150 billion in total losses.[2]

- The costs of such losses will surely continue to rise in an era of increasing demand for electricity and as more people work outside of the office and consumers begin to plug in not only their phones and laptops but also their cars.

- Even without the smart grid there would be significant investments required to keep the current antiquated system operating, including expansion to meet growing demand.

- Without the smart grid we can't develop insights and persistent monitoring of the system to develop an accurate understanding of ongoing usage patterns and evolving needs.

- Though hard to quantify, there certainly will be efficiency, safety and security benefits of much deeper knowledge about real-time events in and around the power grid, as well as environmental and other benefits from modernization.

[1] "A dramatic rise in power failures", Face the Facts USA, August 19, 2012.

[2] *The Smart Grid:* An Introduction, U.S. Department of Energy, Washington, DC, December 2008.

## KEY INVESTMENT AREAS & NEXT STEPS

America's incredible but also increasingly outdated electrical grid is in need of significant investment. Even the U.S. Department of Energy has assessed the grid to be, "aging, inefficient, and congested, and incapable of meeting the future energy needs of the Information Economy without operational changes and substantial capital investment over the next several decades."[3] And yet an American Society of Civil Engineers (ASCE) study found present levels of annual funding leave a significant gap, and that without increased investments, the failure to invest adequately and strategically, "will result in a cost to businesses and households, starting at $17 billion in 2012 and growing annually to $23 billion by 2020 and $44 billion by 2040. The cumulative costs of power outages approach $200 million by 2020 and $1 trillion by 2040."[4] Such numbers are intimidating, but so is the fact that we need perhaps as much as $1.5 trillion of investment over the next 20 years if we fully invest in a national smart grid.[5]

Aging assets in today's grid further increase the urgency. "In the United States, the average power generating station was built in the 1960s using technology that is even older. The average age of a substation transformer is 42 years, but the transformers today were designed to have a maximum life of 40 years."[6] Furthermore, "In 2011, Americans experienced a combined 104,406 hours of power outages across the country (4,435 incidents), up 67 percent in just three years."[7] More to the point, some 20 percent of the sustained outages (defined as lasting more than one minute) were caused by failing electrical equipment.[8]

Fortunately, according to some estimates fully implementing the smart grid could save $46 billion to $117 billion over 20 years in the avoided construction of new power plants and power lines, because a smart grid

[3] "Grid 2030: A National Vision for Electricity's Second 100 Years", U.S. Department of Energy Office of Electric Transmission and Distribution, July 2003.

[4] American Society of Civil Engineers, "Failure to Act: The Economic Impact of Current Investment Trends in Electricity Infrastructure", April 26, 2012, p.40.

[5] "U.S. electricity blackouts skyrocketing", Thom Patterson, CNN, October 15, 2010 7:26 p.m. EDT.

[6] "What the Smart Grid Means to Americans", U.S. Department of Energy, accessed November 2012.

[7] "A dramatic rise in power failures". Id.

[8] *Ibid*.

- ***A stronger power grid will be more reliable, significantly reducing the immense cost of power outages for American consumers and businesses. The 2003 blackout in the Northeast U.S. and Canada caused upwards of $6 billion in economic losses.***
- ***A state-of-the-art high-capacity transmission line can carry as much electricity as six standard lines, at 1/3rd the cost, using 25 percent less land, and with 1/10th the line losses.***
- ***Smart grid enabled energy management systems have proven in pilot projects to be able to reduce electricity usage by 10–15 percent, and up to 43 percent of critical peak loads.***

***- Derived from multiple sources as compiled by the Energy Future Coalition's "Transmission Smart Grid Fact Sheet", February 20, 2009***

would use electricity so much more efficiently that we would need less new generation capacity.[9]

Additionally, assessments of costs versus benefits also must include not just routine operations and equipment upgrade costs but also the magnitude of potential future failures. As we continue to develop our ever more interconnected and increasingly electricity-dependent society, the potential costs of even a single incident continue to rise. For example, many Americans remember when overgrown trees on power lines triggered the Northeast blackout in August 2003, an incident that then cascaded across an overloaded regional grid. As CNN has reported, "An estimated 50 million people lost power in Canada and eight northeastern states. Smart grid technology, experts say, would have immediately detected the potential crisis, diverted power and likely saved $6 billion in estimated business losses."[10]

## THE BENEFITS OF INVESTING IN RESILIENCE

Embedding resilience within the electrical grid is about three main categories of investment: 1) managing and meeting overall demand to help avoid an adverse event; 2) expanding alternatives or substitute systems before and after an event; and 3) enabling rapid reconstitution if and when a disruption does occur. Fortunately, the implementation of each type of solution often carries over benefits across to one or both of the other categories, for the tools and the knowledge that can help avoid an event can also be useful in response and recovery efforts. A few specific examples of improvements in terms of these three categories are detailed below.

### Managing and Meeting Overall Demand

One clear need within the mission to manage demand is to improve the efficiency of the performance in terms of the generation and delivery of the energy we already create. Indeed, as one industry player has noted, "Around two-thirds of primary energy is lost, mainly due to power conversion, and up to 16% of the electricity generated never reaches users – it is lost by the networks, like water leaking from a pipe. The U.S. Energy Information Administration calculated that electricity lost in transmission and distribution cost the economy $20 billion in 2005."[11] Investing in more modern means of generation to improve efficiency at that point in the process is certainly required, but even addressing the 16% lost during transmission represents a significant potential savings. Solutions to these two issues require the use of more modern facilities and also upgraded and more technologically advanced equipment that can measure power flows across the system quickly and at a more granular level.

Another key aspect of managing demand is to incorporate smart grid solutions that reduce the load required during peak periods. The most often discussed step in this direction is the use of smart meters tied to two-way communications between producers and consumers. This type of system, if properly configured with interoperable standards to ensure complete interoperability, would allow consumers to be notified when rates are higher because of rising demand so they can make an informed decision about their current demand or even allowing the power companies to directly modulate a customer's periodic demand based on pre-negotiated terms. This has the potential for substantial savings in terms of the need for new plants that are only used during peak periods.

[9] "What the Smart Grid Means to Americans", Id.

[10] "U.S. electricity blackouts skyrocketing", Id.

[11] "Challenges of electrical grids", Alstom, accessed November 2012.

> ***It is becoming increasingly difficult to site new conventional overhead transmission lines, particularly in urban and suburban areas experiencing the greatest load growth. Resolving this siting dilemma, by a) deploying power electronic solutions that allow more power flow through existing transmission assets and b) developing low impact grid solutions that are respectful of land use concerns, is crucial to meeting the nation's electricity needs.***
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> ***- Grid 2030: A National Vision for Electricity's Second 100 Years, U.S. Department of Energy, July 2003***

The Department of Energy estimates, "Hooking up $600 million worth of new smart appliances to the smart grid could provide as much reserve electric power for the grid as $6 billion worth of new power plants."[12]

A third and equally significant aspect of managing demand is to devise better and more efficient means of storing energy for later use. While the primary focus in this regard has been to develop larger and more powerful batteries, several more conventional and mechanical methods also are in use and could be expanded. These include, for example, using surplus power during high production times (i.e., during daylight for solar powered systems or during strong winds for wind mills, etc.) to pump water uphill to fill a large water reservoir that can be released later to power the generators in a dam, or pumping air into an underground cavern and compressing it to more than a thousand pounds per square inch, then releasing it during the next day to spin a turbine. Expanded use of such storage techniques could help to even out the cycles of power generation and usage, thus reducing the peak-load problem and the need to invest in costly peak-load-only generation capabilities.

### Expanding Alternative Sources

Given the desire to ensure the flow of electricity regardless of what challenges or changes may occur, there is a need to ensure the availability of supplemental electrical power for routine use as well as to be available if the main grid should be impaired. Perhaps the most important means of increasing additional sources of energy supply across each of the nation's three power grid segments is the rather obvious strategy to connect them together, such that if one were affected it could draw power from the others.

An effort is currently underway to achieve this idea, although funding is uncertain and the timeline is not yet finalized. Located in Clovis, New Mexico, where the three grids come closest to each other, the Tres Amigas Superstation would connect the grids with a loop of five-gigawatt-capacity superconducting cable.[13] According to the proposed builder of the nearly $2 billion effort, Tres Amigas, LLC, "First announced in 2009, the Tres Amigas project includes building a hub across 22 square miles of rangeland in eastern New Mexico. It would serve as the meeting point for interconnections that serve the eastern and western halves of the U.S. and a separate grid that supplies Texas."[14] Clearly having the ability to share generated power across the artificial boundaries separating the three main U.S. grids would be a significant improvement in terms of overall resilience.

Another important aspect of developing alternative sources is to use technology to centrally control the generation of electricity from multiple alternative sources, or the creation of so-called "virtual power plants" by using automated control systems able to aggregate and economically optimize the dispatch of distributed generation resources.[15] This approach also helps avoid massive infrastructure investments but also enables efficient and effective integration of variable power sources into the grid on a scale that would be relevant to the overall challenge of generating, transmitting and delivering enough electricity to meet all of our needs.

### Enabling Rapid Reconstitution

Many important aspects of enabling rapid reconstitution of the electrical power system are included in the solutions addressed above, including implementing smart meters and related situational awareness technologies. Such technologies have the ability to help pinpoint anomalies more quickly as well as to better understand where and how a disruption has occurred, which is the first step in fixing the problem. Similarly, modernizing generation and transmission infrastructure and the development of the Tres Amigas Superstation and virtual power plants are also relevant to enabling

12 "Challenges of electrical grids", Alstom, accessed November 2012.

13 Joel Achenbach, The 21st Century Grid: Can we fix the infrastructure that powers our lives?"

14 "Overview (Tres Amigas, LLC)".

15 "Siemens Microgrid Solutions", accessed November 2012.

rapid reconstitution, for each of these actions would increase the amount of available electrical power that could be drawn upon following an adverse event.

An additional investment area with specific appeal in terms of rapidly reconstituting a disrupted or damaged system is the broader use of interchangeable parts throughout the system so as to enable even small stockpiles of spare parts to be able to cover a larger number of critical pieces of equipment. This is essential because the reality of today's grid is that it sprang up somewhat organically and without centralized planning, resulting in hand-made or single-purpose items for which replacement parts are not immediately available. This means that following an event some critical piece may have be made to order and then delivered as a whole, often from overseas and, in the case of large power transformers that can weigh up to 340 tons, using specially designed equipment.

Another potential solution is the use of temporary local area generators that could power large blocks or segments of a city. These so-called "micro-grids" are in essence a cross between the largest of today's truck-mounted mobile generators and a miniature power plant. They could be prepared for use following events, or even pre-positioned and connected for use in advance of an event, most likely serving certain critical nodes such as the New York City financial district, the federal buildings in Washington, DC, and airports or other significant areas.

A final area for consideration is to address systemic interdependencies that lie beyond the grid itself, such as examining regional preparedness for critical infrastructure disruptions that involve telecommunications, transportation, and water networks. Because each of these infrastructure systems operate independently but also are highly interdependent, any assessment of the ability to ensure the repair of impaired or inoperable electrical power infrastructure must account for the inherent need, for example, to have working communications, passable roads, and available water for safety and firefighting.

## CONCLUSION: INVESTMENTS MUST BE SMARTER, TOO

The U.S. power grid of today is fairly effective at producing abundant and cheap energy, and is reasonably reliable relative to routine events and disruptions. However, as noted by National Geographic, "our demands are increasing and changing… we need more, and we want it at different times and from different sources. There are bills to pay with all those adjustments."[16] The large scale of these investments means that the decisions must stand the test of time, with implications for household and business consumers likely to last for decades.[17]

Several of the main issues in considering smart grid investments can be summarized as follows:

- Smart grid estimated cost:
  **$1.5 trillion**
- Smart meters:
  **26 utilities in 15 states have installed 16 million**
- Number of people on average affected daily by U.S. power outages:
  **At least 500,000**
- Yearly cost of U.S. outages:
  **At least $119 billion**
- Number of U.S. electricity customers:
  **143,275,635**
- Number of U.S. power utilities:
  **More than 3,000**
- Total U.S. high-voltage lines:
  **157,000 miles**
- Cost of new high-voltage lines:
  **$2 million/mile when installed underground for greater resiliency[18]**

Significantly, in the decision about the proper path forward we must account for the reality that the current risks facing the nation's electrical power grid are increasing due to many reasons, with the following among the most important:

1. We have a predominantly outdated and decades-old core set of electrical grid infrastructure comprised of several key elements that have been often patched but rarely or never redesigned and modernized, resulting

[16] Joel Achenbach, Id.

[17] *Ibid.*

[18] Thom Patterson, "U.S. electricity blackouts skyrocketing", CNNTech, October 15, 2010.

in increasing repair costs and untold millions of dollars of lost productivity from failures and outages due to practical issues like fatigue, parts failure, and misalignment of the system with how we consume power today.

2. We face ever-increasing demand from growth in both population and in per-person power consumption.

3. We are witnessing a significant uptick in risk across the entire system due to threats and hazards that include natural disasters and shifting weather patterns, terrorist and other asymmetric attacks from state and non-state actors, increasing cyber vulnerabilities, and even traditional threats like disgruntled workers or insider malfeasance.

The obvious conclusion and simple truth about ensuring the resilience and long-term viability of our national power grid is that we have a clear need for greater information in order to better monitor and manage disruptions across the system. Implementation of the smart grid approach would go a long way towards providing the necessary information that could enable us to better protect assured access to this critical aspect of our everyday lives. This is because the smart grid would have three primary impacts:

1. Reducing peak load demand by informing consumers of variable costs to have them reduce their usage during times of peak usage or possibly even having the supply-side utility operators directly control certain demand-side power requirements;

2. Integrating two-way electrical power flow to enable renewable and other distributed generation sources to feed into the grid; and

3. Increasing real-time operator situational awareness of what is happening to and across the power grid, enabling both better routine operations as well as faster response and recovery should an incident occur.

Unfortunately, the nature of the shared dependence on the electrical power grid without shared responsibility for keeping it operating—regardless of what adverse events may take place—results in real-world challenges for developing appropriate resilience across the system. Therefore what is called for is a significant national deliberation on the merits of the required systemic improvements, and the development of a workable roadmap to get us there. Otherwise, we may well wake up one day and find ourselves in a world without instant, ubiquitous and affordable electrical power running all those street lights, communications towers, hospital equipment, and the million other necessities and conveniences upon which we have come to rely.