Rethinking the Grid: Avoiding More Blackouts and Modernizing the Power Grid Will Be Harder than You Think

The challenge of fixing the grid requires greater consensus over the course of deregulation, a new grid architecture, and new regional institutions that allow for political accommodation without sacrificing a shared interest in affordable, reliable, and sustainable energy services. And lots of cash.

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I. Introduction

By electric industry standards, Aug. 14, 2003, began as a fairly normal day in the Eastern United States and Canada. Air conditioners were humming as thermometers pushed 90 degrees across the region. Four generators in the Michigan-Ohio corridor were temporarily out of service. The Davis Besse nuclear plant had been out since March 22, but two of the remaining three had just started their outages the day before. Nevertheless, power flows across the region were not abnormal, and system frequency – the most accurate performance measure – was well within safe limits.

Unseen by nearly everyone, the grid began to degrade, starting with several isolated plant and line failures. Through a combination of unlikely events,
grid operators did not notice and remedy conditions as much as they could have. At 3:50 p.m. a major transmission line over-loaded in Ohio, setting off a cascade of plant and line outages. In the next 23 minutes, nearly 50 million people in eastern North America lost power.

The cost and human toll from the blackout was staggering. Millions of New York commuters walked home across the bridges out of Manhattan; millions elsewhere drove through traffic snarled by an absence of lights and signals. Hospitals and homes for the elderly scrambled to find temporary power. Businesses shut down, incurring an estimated $6 billion in losses. Nighttime satellite photos reveal a swath of North America from Toronto to New York City bathed in darkness for the first time since the advent of electric power more than a century ago.

If it did nothing else, this enormous outage has awakened the U.S. to its underinvested and aging power grid. Historically, U.S. transmission and generation capacity have grown at similar rates. As recently as the decade ending 1989, power demand and the “megawatt-miles” of power lines both grew about 2.7 percent a year. Then the bottom dropped out. The following decade, electricity use continued to grow at the same rate—but new lines increased only 0.7 percent per year.1 If present plans hold, the U.S. will increase transmission lines by only 5 percent during the next 10 years as the capacity of large power generators increases six times as fast.2

The challenges of grid investment and management are not uniquely American. Less than six weeks after the North American blackout, the failure of power lines between Italy and Switzerland threw 50 million Italians into darkness for a day. A series of proposals to increase grid investment and oversight are emanating from Italy, France, Switzerland, and the offices of the European Union. Earlier last summer, Sweden and Denmark also experienced a large blackout. Meanwhile, EU nations are starting to experience organized citizen opposition to building new lines; the so-called NIMBY syndrome (“not in my backyard”) has leapt the Atlantic Ocean.

On both sides of the Atlantic, proposals to strengthen the grid include enforceable reliability standards, financial incentives for new construction, new grid technologies, standardized market rules, and greater authority to site transmission lines. These ideas unquestionably have merit, and a few have a solid consensus behind them. However, these changes alone will not solve the underlying problem. No one entity has the authority, budget, or incentive to rebuild the grid. Even if they did, they would still lack the blueprints.

The power networks of the developed world confront an enormous mismatch between their design, funding, and governance. We must agree on a new technical purpose for the grid, adopt methods of funding consistent with this vision, and sort out the role of regulation and market forces. As this occurs, we need regulatory policies that provide enough certainty to bolster investment during the transition. The mission, funding, and regulation of the power grid are inextricably linked. Finding a solution to this challenge is not only a matter of avoiding future blackouts—it is essential to the creation of a viable, reliable industry.

II. The Old Grid: Function and Funding

The problems facing the grid today are an outgrowth of its changing role as the heart— or more aptly, the circulation system—of the electric utility sector. The original high-voltage grid was grafted on to a set of isolated, local electric companies that sprang up between about 1920 and 1940. To serve their local total demand without blackouts, each utility had to build a “reserve margin” of additional generating plants...
that started up – seamlessly and invisibly to us consumers – when another plant failed. They also built enough lines to deliver the power to their customers, though with much less redundancy in a local delivery system than there is in the interstate grid.

As engineers developed higher-capacity power lines, utilities hit upon a way to reduce costs. Since large plant outages occurred randomly and infrequently, and since the new large lines were cheaper than keeping spare plants running just in case one broke down, why not string a line between two utilities for use during emergencies? If one utility had a plant breakdown, chances are the second utility would not. Instead of each utility keeping a full set of spare plants, each of three connected utilities needed only one-third the spare capacity running. In other words, the original grid was a form of reliability insurance – a way of pooling plant outage risk. It was a cheaper way to protect against blackouts than building more nearby power plants.

The original size of the grid was driven by the required level of reliability and tradeoffs between lines and plants as the cheapest means of maintaining reliability reserves. Regulators would first specify the level of reliability they wanted utilities to achieve, such as a maximum frequency of blackouts. Utilities would plan their systems and grid connections to achieve this level of reliability at lowest estimated cost, given siting constraints. This involved complex tradeoffs among the locations suitable for new power plants and transmission lines as well as the sizes and types of plants. For example, U.S. regulators wrote in 1981 that:

Essentially, there is a tradeoff between adding generating reserve capacity at $200–300 per kilowatt for peaking units versus installing additional transmission facilities (say, 500 kV at $300,000/mile) to achieve an equivalent reliability benefit to the system. In general, transmission to some distance can be added much more cheaply than generation, although ... transmission only provides access to reserve capacity; it cannot substitute for it.3

III. Partial Deregulation and The Grid’s New Role

In much of the world the structure and regulation of the electricity industry has changed profoundly. The core of the change involves the construction and operation of power plants – the business of generating power – as distinct from transmitting that power over the grid. The epochal change occurred when the generation function was severed from transmission and allowed to become a separate, less-regulated industry made up...
of independent deregulated power plant owners.

On the surface this change seems quite simple. Take all existing power plants and divide them between several new deregulated owners. Let them compete to sell power to customers over the wires and let them build new power plants wherever they think they can make a profit. The laws of supply and demand will guide investment, and the price of power generation will be set by the market rather than by regulators.

The hidden difficulty in this seemingly simple plan is the transmission grid. In an industry with competitive generation, the function of the power grid has suddenly changed. The grid has now become the sole means by which generators can compete. Without access to customers via the grid, no power plant can sell a dime’s worth of power. Physically and economically, the grid is the market’s only delivery channel.

Understanding this reality from the start, power plant deregulation has always been accompanied by a new regulatory paradigm for the transmission system. Whereas the old grid was purely reliability insurance, upon generator deregulation the grid owners were required to provide “open access” for all generators.

How does one change a regulated transmission grid to “open access”? The easy answer is to change the rules and regulations applying to existing transmission owners and operators. As part of the power plant deregulation process, grid owners (who remain regulated) are required to offer equal terms of service and to allocate available transmission capacity to all generators who request it. Sometimes grid capacity is awarded on a first-come, first-served basis and sometimes capacity is auctioned off to the highest bidder.

Setting new rules is the easy part—though in practice it has been anything but easy. The hard part begins with the recognition that, on the day deregulation begins, the size of the power grid is not matched to its open access role. The size and type of power lines in place when deregulation starts are the lines the old integrated industry needed to provide reliability. The transmission capacity a deregulated market needs to make competition work well is a very different amount. And the initial capacity is only the first of many deep-seated differences.

In a competitive industry, existing power plants are allowed to change their output levels every 10 minutes.

As a matter of design, engineering, and control, the grid was not intended to function under the partially deregulated system the U.S. has evolved into and Europe is headed towards. Following the blackout, power industry consultant Jack Duckworth wrote:

… Just as a wicker basket can’t be used to carry water, a transmission system which was designed to operate in a regulated, vertically integrated, power market can’t be expected to carry power generated in a deregulated, build-it-anywhere-you-like, power market.5

The new role of the grid has extensive implications for its proper size, design, operation, and management. The problem is that we don’t understand or agree on them all.

A. Size and stress

The original grid was designed to deliver power from a predictable set of power generators to predictable locations over a period of decades. Engineers could model flows on the grid and how they change when plants or lines go out. This ability to model the system gave them the confidence to decide how many power lines were needed to achieve any level of reliability at lowest estimated cost. Ultimately, calculations like this determined the amount of grid now in place in most of the U.S. and Europe.

In a competitive generation industry, existing power plants are allowed to change their output levels every 10 minutes, often dramatically altering the direction of power flows over the course of hours. Power traders can agree to sell power from a plant to a load

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hundreds of miles away, from Chicago to New Jersey, Canada down to the southern United States, or Germany to Norway via Finland and Sweden. It is nearly impossible to predict power flows accurately a few months in advance, much less several years. Meanwhile, new power plants can locate wherever they are so permitted, adding new flows that may or may not have been predicted.

Predictions aside, it is not at all clear what the “right amount” of transmission capacity is supposed to be. The amount of transmission provided to the market can range from enough capacity to send any generation anywhere it wants to go (zero congestion costs, in technical terms) to the present amount, which is heavily congested in many spots. Where between these two extremes is the right amount?

In dollar terms, the estimates of investment required to restore the U.S. grid vary greatly, depending in part on whether one considers non-transmission investments as substitutes for adding more wires. Taking a worldwide view, the International Energy Agency issued a shocking 30-year estimate that $2.5 trillion investment would be required in the power grid largely to keep up with world demand. In the U.S. the Electric Power Research Institute and other industry sources estimate that $50–100 billion in investment is needed, in part because many in the industry are thinking about fundamental retooling, which will eventually be necessary in any case. Others argue that the cost is only a few billion, and that investment in the grid should not displace cheaper investments in distributed generation and energy efficiency. In contrast to the lack of agreement on the right amount of grid investment, evidence that the grid is increasingly overloaded is abundant. Power engineering expert Tapani Seppa writes:

An active debate is underway between proponents of a deregulated, competitive transmission sector and those who believe market forces will not produce effective outcomes.

Fifteen years ago, it was extremely rare to operate a line at above 75 percent of its rated capacity. Today, such occurrences are commonplace. Thus, when emergency overloads occur, a conductor’s temperature can already be very close to its design temperature, or perhaps even above it, giving operators very little time to react to the situation, even if they know about it.

The rate at which the system is becoming congested is rising rapidly. As of 2001, 21 of the 186 monitored eastern U.S. transmission paths were congested more than 10 percent of the time. A forecast of congestion across the U.S. in 2004 finds that congestion on all monitored paths in the eastern U.S. begins at 19 percent of all hours and rises as high as 85 percent around New York City. The grid is simply being run more intensively, less predictably, and with a much smaller margin for error than ever before.

IV. Let the Market Do It?

When important regulated investments are falling short, and there is no agreement on how much more should be built – much less who will pay for it – it makes sense to ask whether there is a different approach. For competitive industries, we don’t ask ourselves whether there is enough (say) capacity to produce office supplies or pet food. We assume that market forces will beget sufficient investment in producing the amount of these goods consumers are willing to pay for.

An active debate is underway between the proponents of a deregulated, competitive transmission sector – known as merchant transmission to those of us in the trade – and those who believe market forces will not produce effective outcomes in this unique sector. The debate has pitted some of the world’s leading electric power economists against one another and is nowhere near achieving consensus.

The case for merchant transmission is simple and predictable. Let entrepreneurs figure out how much transmission the market will pay for by offering to build it
at a profit. Require these merchants to follow reliability rules (whatever that means), but let the market figure how to build it and how to pay for it. Forget open access and regulation—let competition between lines discipline prices.

Another theoretical advantage of merchant transmission is that it can be placed more easily in a framework where large-scale grid investments compete against decentralized alternatives. For example, suppose there is a choice between building another transmission line and building two dozen small power plants at the far end of the line inside a major city. (In reality, the tradeoffs are rarely this simple, but put this aside for now). If both the builder-sellers of the small plants and the builder-sellers of the power line offer adequate substitutes to the market, the lowest-cost solution should win out, to the benefit of consumers.

This is a seductive argument, but it avoids a number of theoretical and practical defects that together constitute the case against major reliance on unregulated transmission. Briefly, the issues are:

- **Entry barriers.** Competition requires that there be no major barriers to entry or exit. Obtaining permits to site or expand transmission lines is difficult, and the number of corridors that authorities will allow for lines is very limited.

- **Exclusive facilities.** While there are many alternatives to new sites or lines, there are also instances in which upgrading existing facilities is cheapest. But someone already owns these facilities, and this gives them a competitive advantage. Mandating access to existing owners’ sites does not work well, as we learned from our attempts at facilities-based local telephone competition.

- **Economies of scale or lumpiness.** Transmission lines and other grid upgrades are lumpy—larger upgrades are much cheaper. The size of the cheapest upgrade is often not discretionary.

- **Positive externalities.** Nearly every upgrade to the transmission system benefits a wide group of customers. Some of these benefits are in the form of greater reliability enjoyed by all; others come from lower energy costs or greater choices of supply. Remember the difficulties in predicting flow patterns? These difficulties make it nearly impossible to identify all of the beneficiaries of a grid upgrade over the long term—and yet upgrades have an economic life spanning many decades.

- **Negative externalities.** Sensible grid upgrades have positive overall benefits, but quite often there are several groups that are made worse off by the upgrade. For example, power buyers in an area with a power plant surplus enjoy a buyers’ market. When a grid upgrade is built to ship more of that cheap power out, local prices rise.

- **Open access rules.** As noted, present regulation requires all grid owners to give equal access to all buyers. There are many ways this requirement might conflict with allowing deregulated transmission owners to charge whatever they want to whomever they want—ideally disciplined by competition, not rules. Even with a perfectly competitive future outcome.

- **Reliability rules and procedures.** One way or another we are heading towards mandatory reliability rules that all grid owners and operators must follow. Ideally, this need not disable competition between grid builders—airlines continue to compete as they conform to pervasive safety and reliability procedures. However, reliability rules will undoubtedly create winners and losers among transmission investments, and this is sure to beget enormous political and legal pressure.

- **Existing owners.** Under the U.S. Constitution, existing regulated transmission owners cannot have their property effectively confiscated by regulatory policy changes. During the original deregulation of generation, this
led to many protracted legal and regulatory battles over so-called stranded costs.

In some countries around the world, such as Australia and Chile, these factors have not been so powerful as to dissipate the economic viability of merchant transmission—at least not yet. In the U.S. and Europe, however, these factors have so far greatly limited the viability of merchant transmission. There is only a single working merchant line in the U.S., and it has given its owner so much legal and regulatory grief that its owner is repeatedly considering abandoning the business altogether. Several others are proposed, but their future is uncertain.

In my view, the realities of the U.S. and European power industries, including their politico-economic entrenchments and complex legal frameworks, suggest a rather limited role for deregulated transmission. Absent a radical political shift, perhaps triggered by a series of additional large blackouts, investment in the grid will remain predominantly influenced by regulatory control over transmission pricing, operation, and entry.

V. What’s Stopping Regulated Transmission?

From the standpoint of investment risk, regulated investments are nearly as good as it gets. In simple terms, regulation of the grid ensures that any firm that gets permission to build a power line is guaranteed the opportunity to be able to add the cost of the upgrade into its rates, including a fair profit margin. With a deal like this, why aren’t regulated utilities lining up to make investments that offer very low risk returns?

Thanks to the blackout, some utilities are. Prodded by regulators, U.S. and European grid-owning utilities are suddenly laying plans to build more transmission. A recent survey in the U.S. finds that utilities are getting ready to add much more new grid capacity than in recent past.

But just exactly how did we get in this jam in the first place? Hasn’t transmission been a safe regulated investment all along? And what does this say about our ability to maintain an adequate regulated grid? To answer these questions, we need to go back in to the history of power deregulation in the U.S.

A. Problems introduced by deregulation

At best, most Americans are vaguely aware that interstate wholesale (bulk) power sales are under the jurisdiction of a federal regulatory agency known as the FERC, while retail power sales are state-regulated. Most know whether their own state is one of the 17 states that deregulated retail sales or the 33 that continue to have state rate control.¹⁰ Most are shocked to hear that there has never been a federal law calling for either uniform wholesale or retail deregulation of generation—not to mention the fact that transmission and distribution continue to be fully rate-regulated. Instead, Congress enacted two rather narrow provisions, in 1978 and 1992, respectively, that allow a certain class of deregulated wholesale generators to exist atop an otherwise unchanged industry.

While Congress would not have passed an outright deregulation bill, neither did they forbid states from doing so. As long as there were no problems it was content to let matters evolve via FERC rule changes. This “deregulation by rule creep” accurately reflected a cautious federal endorsement of deregulation so long as it was not forced on any state and was somewhat acceptable to the huge mixture of firms that constitute the industry—from small municipal and rural cooperative systems to large multinational holding companies.

The result is a wide spectrum of regulatory arrangements, from fully traditional rate regulation by states to fairly extensive retail deregulation, or retail choice. Seventeen states have a form of
retail deregulation, sometimes quite limited. In the wake of the western power crisis of 2000–2001 a few western states slowed or reversed deregulation, and everywhere else restructuring has stopped. The non-partisan National Commission on Energy Policy bluntly observes that, even before the blackout, industry restructuring had “derailed.”

The contrast between this piecemeal approach and that of other deregulating nations is dramatic. In England, the one nationally owned power company was split into several deregulated generation companies and a single, nationwide transmission company. The power grid happened to have ample transmission capacity, a new independent regulatory agency was set up, and the whole thing began with a bang. Even this relatively complete scheme did not prevent competitive problems initially – the market system was fully redesigned in 2001 – but at least the basic structure of accountability was uniform and understood at the outset.

On this side of the pond, no one checked to see whether the transmission system was the right size to enable deregulation to work, nor whether FERC had the rules or authority in place to make it work. Those who were familiar with the condition of the U.S. grid warned that our system was neither designed nor operated for widespread decontrol. Furthermore, everyone assumed deregulation could co-exist just fine alongside fully half an industry that was still regulated or publicly owned. No one was sure how the inevitable tension between states with low-cost power and states hungry for it would play out. “It wasn’t that the cart was put ahead of the horse,” one transmission executive said recently. “It was that policymakers were trying to drive the cart without a horse.”

Another mortal blow came in the form of political unwillingness to separate the vertically integrated industry into distinct generation, transmission, and distribution companies (as in the U.K. and most other deregulated nations). Although there are clear savings from vertically integrating generation and transmission, such integration can create an adverse incentive for integrated firms to limit access to their transmission lines. After all, since the 1920s the business model of integrated utilities was to sell your own generation over your power lines to your own customers. Generation competition meant that your competitors used your own transmission lines to steal your customers and/or export your cheap supplies. Even today, many large utilities either do not want to or cannot divide into totally independent generation, transmission, and distribution businesses.

B. Uncertain federal policies

While Congress was content to sit on the sidelines, it has been part of the policy agenda of FERC and White House leadership during the past 10 years to expand deregulation. Rather than ask for added federal authority or a mandate Congress would not agree to, the FERC adopted a series of rules within its limited authority intended to create competitive generation markets, while keeping transmission regulated. Lacking a clear national consensus and adequate authority, it has been forced to adopt a constantly evolving thicket of rules and policies governing the regulated grid. This constantly shifting, always voluntary, and frequently litigated transmission policy landscape has been by far the largest impediment to grid expansion over the past 20 years.

In financial terms, the impact of uncertainty can be measured via the tradeoff between risk and the return on investment earned through regulated rates. Much attention has been paid to the argument that grid investment is too low partly because regulators have not granted high enough rates of return to transmitting utilities to match the risks of
transmission investment. In response to these arguments, FERC has gradually raised the rates of return on transmission investment from around 9 percent to as high as 13.5 percent for some projects.

My colleagues who study the subject have pointed out two important things about transmission rates of return. First, because transmission is a small portion of the total industry asset base, and yet so important, erring on the side of high rates of return, and thus possibly over-incentivizing investment, is far better than having too little grid.15

However, here is where our unwillingness to truly restructure the industry bedevils us. The transmission rates of return set by FERC do not apply to vertically integrated utilities, i.e., to the portion of transmission assets that are dedicated to traditional regulated retail service. Only state regulators can boost transmission ROE for the portion of transmission bundled into retail rates. But state regulators are understandably reluctant to raise retail electric rates in order to expand the grid, lose use of cheaper local supplies, and be forced to raise rates still again.16

My colleagues’ second observation is that the policy uncertainties that affect investment returns have an extremely strong impact on investment. Ever-shifting policy changes increase the risk to investors greatly, often overwhelming the positive impacts of a higher allowed return.17 Without question, Wall Street agrees. A typical headline in the recent energy trade press trumpets that Regulation Uncertainty Tops Energy Investor Woes.18 “Return on investment is not as important as regulatory certainty in attracting Wall Street money to many needed projects,” notes Wall Street analyst Christine Tezak.19

Because it does not involve rate increases, greater policy certainty would ultimately lower transmission rates by reducing the level of return necessary to attract investment. Policies that reduce the variability of cash returns, and especially the possibility of a significant loss, have the greatest impact. All in all, our unwillingness to confront lack of consensus on electric deregulation and overcome the consequent disincentives to build the grid are taking their toll.

VI. The Future Grid

In today’s partially deregulated industry the grid serves a multiplicity of roles. First it continues to provide redundancy and reserve-sharing for the system as a whole. In this role, the grid must be planned and controlled to place limits on flows and force all grid users to abide by rules that prevent overloads.

The grid is also the fulcrum balancing very different approaches to providing affordable energy services. Once upon a time the only known solution to an overloaded grid was a larger, higher-voltage power line. Now a transmission owner seeking to relieve an overload might choose from measures as diverse as new control technologies, burying new “superconducting” power cables in place of existing lines, a demand response program that eliminates the overload by cutting demand during peak times, or installing solar-electric cells and gas microturbines on the far side of the overload to boost supply.

Finally, there is an added new dimension to the grid known as power quality. We tend to think of electric power as a perfectly homogeneous product—alternating current at 120–240 volts, 60 cycles. This is true, but this voltage and frequency is allowed to deviate slightly, and to have momentary hiccups too short to affect older appliances, but costly to new ones. Our increasingly digital economy requires power that meets standards that are more complex and more demanding than existing criteria.

At present, the conflicts between these three roles are played out in the transmission planning process and sometimes
in state regulatory and planning fora. In regions of the U.S. without regional transmission organizations (RTOs), this occurs through specialized organizations or the somewhat less formal planning process of the North American Electric Reliability Council (NERC). Where RTOs have formed, FERC requires them to do regional transmission plans that involve all affected states and stakeholders. However, new construction projects included in these plans are not enforceable and usually require explicit project-by-project approvals by state regulators and other agencies.

The idea of RTO-based planning is that these regional agencies, though lacking much authority, can gain enough consensus to enable grid expansion sufficient to accommodate both commerce and reliability. The planning process should involve state and local regulatory agencies, whose approvals are usually needed for new projects, as well as other stakeholders who may advocate against particular projects, sites, or technologies.

In the best of times this is an exceedingly tall order. First, the willingness of agencies to cede authority (directly or indirectly) over energy facilities under their jurisdiction varies greatly across the U.S. Because state authority remains pretty uniform, investors typically do not view RTO plans as anywhere near actionable until state approvals are in place. In areas of the U.S. where RTOs are starting to do transmission planning, state regulators have started to increase their interaction with RTOs. The hope is that this will lead to “one-stop shopping” for new lines, which frequently need the approval of several states as well as the RTO and FERC. The fear is that RTO processes will become a “third layer” of regulation, without replacing state or federal approvals.21

Examining tradeoffs between different transmission additions, additional generators, and small-scale alternatives is also extremely difficult, analytically as well as politically. Although much research confirms that the cheapest life-cycle energy services frequently come from efficiency improvements, most approaches to increasing efficiency involve state or local utility programs funded in part by local rates or fees. The same applies to many small-scale generation technologies, with exceptions. RTOs and FERC have neither jurisdiction nor institutional capabilities in these areas. While this is changing over time, RTOs are mainly creatures of the large-scale power industry focused on traditional generation and transmission hardware.

The challenge is illustrated by a recent extensive inquiry into the evaluation of so-called demand-side grid alternatives by a consortium known as the New England Demand Response Initiative. This effort was funded in part by the region’s own RTO, ISO New England, and examined the incorporation of non-grid alternatives into ISO-New England’s processes, which are among the most comprehensive and complete in the nation. Yet the NEDRI report concludes:

To anticipate and resolve system challenges and bottlenecks requires analysis of a range of potential solutions including transmission investments, transmission operations, strategic generation, and demand-side programs and investments … NEDRI recommends that the regional planning process employed in New England be organized and conducted with a clear capability to assess all technically feasible, reasonably priced solutions that could meet reliability objectives. The region’s planning process should review a complete array of potential solutions to system deficiencies, and consider their costs and benefits, and their ability to address reliability needs.22

The report goes on to note that, even in what is one of the most closely integrated and cooperative regions with retail deregulation, planning and implementation of non-grid alternatives was highly fragmented and regionwide funding was needed.
A. Rethinking the grid’s basic architecture

As a technical matter, the present structure of the North American grid takes the form of two very large, heavily interconnected alternating-current (AC) systems spanning all of North America except Texas. Each of these grids is a gigantic web of plants, lines, transformers, and control centers, all operating at six or seven standard voltage levels and exactly the same frequency. Power flows freely across this web via the paths of lowest resistance, meaning that it cannot be directed from plant A to customer B via any one route, and no one can distinguish anyone’s power from anyone else’s—it is one big pool of flowing electrons.23

The three gigantic grids are controlled in real time by about 140 control centers. Each control center monitors one portion of the grid and communicates with their neighboring control centers. These control centers are the heart of the NERC voluntary operating procedures that govern reliability today. Control area operators have hundreds and hundreds of pages of operating procedures that spell out the capacity of each line in the system, allowable flow patterns, procedures to alleviate sudden overloads, and so on.

Perhaps the single most important goal of NERC’s operating and planning procedures is to avoid the sort of cascading failure that engulfed the Eastern U.S. on Aug. 14, 2003. NERC procedures are designed to alert control area operators in other areas to problems in one control area and essentially disconnect their part of the system from the part with a problem. In short, the underlying architecture of the grid and NERC’s operating procedures is a free-flowing AC grid that disconnects from troubled areas when needed.

Of course, this didn’t happen on Aug. 14. There were several reasons, but the scale of the blackout did not surprise many veteran observers of grid operations. One of them, George Loehr, argues that neither mandatory rules nor greater investment nor greater regulatory certainty will restore reliability. Instead, Loehr argues, the grid must be fundamentally redesigned.

Loehr argues that the grid is simply too big to manage reliably using free-flowing AC current.24 He suggests that the three megagrids be divided into seven or eight smaller AC grids, each of which is owned by a series of direct-current (DC) lines. Whereas AC lines and NERC control procedures require operator intervention or very complex systems to control cascading failures, DC lines’ inherent controllability means that cascading is impossible.

The point of this digression into Loehr’s ideas is not to argue that they must be done. Rather the point is to illustrate that a fundamental rethinking of the basic engineering structure of the grid is an essential part of getting grid investment right. This will not occur until new standards, the accompanying system-wide architecture, and the total costs of re-engineering, and the authority and accountability are all assembled in one coherent plan.

B. The smart, digital grid

Different but equally radical ideas are emanating from factions of the power, high-tech, and global R&D establishment. Two distinct and substantial consortia are each advancing the concept that the industrialized world needs to change the grid from largely passive or “dumb” to a self-regulating “smart” configuration.

At present, the grid is primarily a one-way delivery system. Power is pumped in at the power plant and extracted in homes and offices. The monitoring and control of the grid primarily ensures that the total amount of power is pumped in to equal demand (which is necessary at all times to avoid blackouts) and that each link in the delivery system is not overloaded. Control systems are designed to take lines and plants...
out of service when overloads occur, usually redirecting flows without the need for any customers to lose power. However, simple element-specific protection logic cannot think about the big picture, it can actually contribute to rather than protect against larger system-wide failures.25

The technology in this system is all configured to be monitored and centrally controlled by the aforementioned 140 control centers scattered around the U.S. Although much of the protection circuitry on the grid operates automatically, the main thing these circuits can do is remove equipment from the grid to save it from burning up—just like the circuit breakers in home fuse boxes. Furthermore, much of the control hardware was made prior to advances in digital and solid state control devices, so it still uses slow mechanical switches. The most advanced transmission hardware can actually change the electrical attributes of individual power lines so that power can, for the first time, be controlled and routed over large AC systems.

As power generating technologies become smaller and more efficient, more are being installed next to or inside commercial and large residential buildings. These distributed generators send small amounts of power into the grid, but the grid is really not designed to receive power (in small or large amounts) at what the grid sees as the user end of the system. Similarly, the devices that use electrical power are almost always passive, i.e., they simply take as much power as they need from the grid and do not otherwise communicate with or change in response to grid conditions.

The smart grid concept changes all this. In its most elegant formulation, every device that generates or uses electricity plugs communicates seamlessly with supercomputers that automatically control these appliances and generators in response to changing grid conditions. This allows much more sophisticated control of the grid and potentially much higher reliability and power quality.

Consider the example of a large power line suddenly going out of service. In the passive grid, sensors would notify control area operators, who would respond – partly automatically, partly by hand – to increase power plant output in certain locations, possibly stop new transmission transactions, and contain the outage. In a smart grid, sensors locate the outage and computers rapidly and automatically analyze hundreds of response actions. These actions might include automatically turning off or turning down thousands of individual appliances voluntarily pre-programmed by their owners—to adjust usage when called on, in exchange for a credit on their electric bill. Alternatively, the system could turn up the output of large or small generators, connect superconducting storage devices to the system, and adjust certain settings on power lines that control their flow.

Two industry groups have been advancing the notion that the U.S. and other nations need to transform the grid from passive to smart over the next 20 years. One group, know as the Consortium for Electric Infrastructure to Support a Digital Society (CEIDS) is led by the Electric Power Research Institute, an industry-funded R&D consortium. A second consortium, the GridWise Alliance, includes IBM, Alstom, Sempra Energy, and several national laboratories. Both groups share the objective of transforming the grid into a smarter, more efficient, interactive, and self-healing entity.

Under the Bush Administration, the U.S. Department of Energy had adopted the creation of a modernized grid as one of its main long-term objectives even prior to the blackout. Accelerating its actions following last August, it recently released Grid 2030, which it calls “a national vision” for a smart grid created by 2030. It has also assembled industry participants to create a sweeping catalog of technological develop-
ment needs and established a new office within DOE to focus entirely on power transmission.

C. Barriers, again

While it is certainly encouraging to see the likes of DOE, EPRI, IBM, and other R&D leaders recognize that the grid needs a new vision, a new architect, and lots of new investment. But unfortunately, the history of U.S. energy policy is littered with examples of problems that DOE and its industry colleagues recognize far easier than they can solve.

DOE began its recent push with an elegant “vision meeting” in which it asked a cross-section of distinguished industry experts about the proper goals, elements, and challenges confronting a smarter grid. Participants were allowed to vote, indicating where DOE should put its emphasis in creating the grid of the future. Tellingly, the technological aspects of the road map received very few “challenges” votes. No one doubted that engineers will succeed in designing smart appliances, better control systems, and the rest of the hardware needed for a smarter grid. The challenges receiving nearly all the votes? Lack of stable regulatory climate; a fragmented and balkanized industry; and environmental regulations.

The leadership of DOE is essential, and so is the support of industry consortia like CEIDS and GridWise. However, none of these entities have much to do with the establishment of transmission policies, rates, or funding. FERC is independent of DOE and operates in a framework of applications, complaints, hearings, and orders. DOE is an R&D agency that helps industries and national labs invent things, but traditionally has neither the funding, the authority, nor the capability to ensure that new technologies are adopted. There is no law that gives DOE the tools to makes its vision of Grid 2030 a reality, much less the funds to do the job. One commenter was particularly artful: “The technical issues are too complex for the government to be the solution and too costly for private capital to be committed.”

VII. Conclusion

Wall Street experts have been acutely aware of the unpredictability of U.S. electric policies for many years. In their view, the problem remains as pressing as ever. After the blackout, Standard & Poor’s analyst Peter Rigby wrote:

While the blackout creates a sense of political urgency, addressing the problems of the nation’s grid and, indeed, the regulation of the entire U.S. electricity industry, will be no simple matter. The politics of power are divisive and little consensus exists about how (or whether) to continue with regulatory reform. And even if policymakers succeed in crafting a comprehensive solution to the problems of the nation’s electricity grid, the regulatory treatment of the costs needed to upgrade the infrastructure remains uncertain... Gaining consensus among industry participants and stakeholders looms as a Herculean task.

Mr. Rigby is correct, but the challenges are harder still. The architecture of the grid no longer matches its role, no one has the authority or money to change it, and Europe is right behind us on pretty much the same rocky road. As the world adopts mandatory reliability rules, builds some new lines, and takes other steps, we must not fall victim to the belief that we’ve faced the deeper problems evidenced by recent blackouts. The challenge of fixing the grid requires greater consensus over the course of deregulation, a new grid architecture, and new regional institutions that allow for political accommodation without sacrificing a shared interest in affordable, reliable, and sustainable energy services. Not to mention lots and lots of cash.

Endnotes:
1. Eric Hirst (consultant in electric-industry restructuring), Expanding...
and practical reasons, most automobile consumers choose to carry only one spare tire, not two or more,” David White, Amy Roschelle, Paul Peterson, et al., *The 2003 Blackout: Solutions that Won’t Cost a Fortune*, ELEC. J., Nov. 2003, at 52. See also IEA: *Electricity Sector Needs $5 Trillion over Next 30 Years*, ELEC. DAILY, Oct. 24, 2003.


15. They write: “At present, it is better to overshoot than undershoot when estimating the cost of capital for electric transmission. Although the allowed return on the transmission assets is a small part of the overall delivered-cost chain, it ultimately is a big determinant of the adequacy of the grid asset base, hence of the quality and value of delivered power. It is now evident that open access is rarely sufficient, by itself, to achieve competitive market performance in wholesale generation. A few days of high prices due to generation market power, possibly aggravated by transmission congestion of limited import capacity, can create price spikes whose costs to consumers or resellers dwarf any potential increase in the rate of return on transmission capital that might be under consideration by the Commission. In our view, a high-priority goal of the regulatory community ought to be to make it financially worthwhile for the various forms of transmission organization to expand.” A. Lawrence Kolbe and Frank C. Graves, *Supplemental Direct Testimony to the Federal Energy Regulatory Commission*, Docket Nos. ER97-2355-000, et al., Oct. 1999, at 5.

16. In addition, FERC does not have any power to set rates, return on investment, or access policies for about a quarter of the U.S. grid owned by customer-owned cooperatives or public power agencies, including those of the federal government. Both versions of the pending energy bill give FERC the authority to set an access tariff for these non-jurisdictional utilities, and to require them to follow reliability rules. In general, however, this non-jurisdictional portion of the industry has not faced the same disincentives to invest in transmission and its portion of the grid is not viewed as the core of the problem. States that adopted retail deregulation made a different but parallel disincentivizing mistake. In deregulating states, regulators felt compelled to show that deregulation would immediately lead to lower...
prices. To prove this, they froze or lowered rates.


18. Restructuring Today, Sept. 15, 2003, at 2. The impact of differences in the degree of political consensus and industry structure are highlighted by the fact that one company, National Grid, owns large transmission systems in both the U.S. and the U.K. In spite of the fact that its U.S. system is three times the size of its U.K. assets, and U.S. power demand continues to grow, it has invested one-third as much in the U.S. as it has in its U.K. grid. Also see, Deregulation’s Dysfunctional, PLATTS ENERGY BUSINESS & TECHNOLOGY, Oct. 2003, at 28–31, and Kiah E. Harris, P.E., Effects of Uncertainty on Market Development: Reliability, Planning and Local Generation, prepared for American Public Power Association, Aug. 2002.


20. As an example, the Bonneville Power Administration is adopting a new transmission planning process that emphasizes a complete range of alternatives. See T. Foley and E. Hirst, Expansion of BPA Transmission Planning Capabilities, 2003 (available at www.transmission.bpa.gov).

21. Because RTOs have no formal state government involvement, and generally do not have much formal participation by stakeholders outside the large-scale power sector, I have advocated the creation of regional energy planning and siting compacts as counterparts to RTOs; see Peter Fox-Penner, Easing Gridlock on the Grid, ELECT. J., Sept. 2001. I am skeptical that RTOs alone are the best solution to regional energy planning and siting, and mandatory (hence universal) RTOs seem unlikely in the near term in any event. Pending House energy legislation authorizes siting compacts, and I think they would provide a regional solution to what is inherently a regional challenge without weakening the political authority of the states.


23. The only exception are a handful of direct-current high-voltage lines that are more expensive, but allow power to be directed across them. These DC links are used to control power flow in special parts of the grid and between the three giant grids that comprise North America.


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### Meetings of Interest

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<td><a href="http://www.energyforum.net/conferences/C502">http://www.energyforum.net/conferences/C502</a></td>
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<td>Electric Utility Business . . From the Inside Out</td>
<td>May 5–6, 2005</td>
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