Greenbang

Data analytics for the smart grid: IBM’s Intelligent Edge

Executive summary

A tremendous amount of data will be generated as the world's energy grids are made "smarter" with the addition of communications-enabled sensors to millions of points on the transmission and distribution networks. Utilities, network operators and other organizations will be able to extract intelligent value from this raw data with the help of analytics tools for identifying disruptions, responding to issues and modeling future demand and generation needs.

Businesses that use analytics most effectively stand to benefit from lower energy costs, reduced waste and more efficient operations, all of which can offer a competitive edge in the marketplace.

Companies that can deliver these analytics tools to their customers *today* give these users an edge at a time when it is greatly needed. Many organizations are finding themselves drowning in more data than they know what to do with, while at the same time, they're struggling to keep costs down and become more efficient.

Energy firms are especially in need of solutions, as they're faced with expanded legislative requirements, rising fuel costs, an increase in renewable power sources and other challenges to their bottom lines.

Those solutions lie with data analytics for the smart grid. ■

Introduction to the grid today

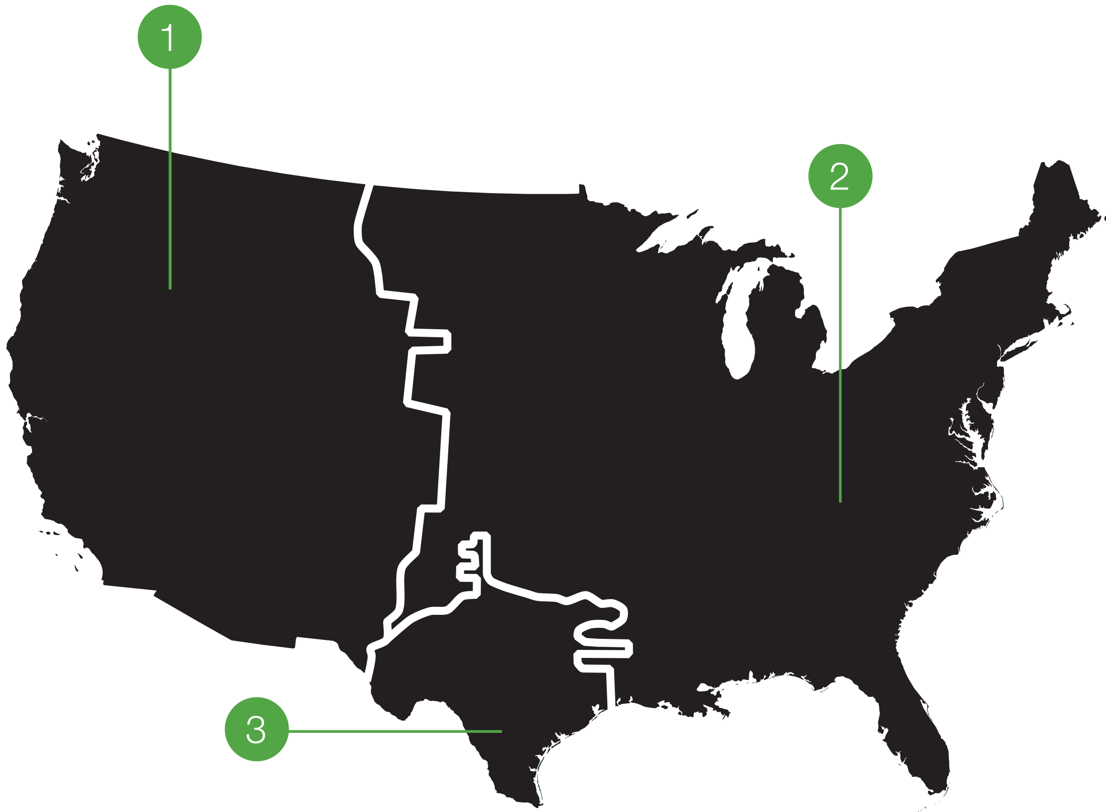
The basic structure of the power grid today hasn't changed much in the past 100 years. As the US Department of Energy notes in its guide to the smart grid, if Thomas Edison, "one of the grid's key early architects," were transported to the present, he would be "totally familiar with the grid."[1]

The electricity grid has been described as "the largest interconnected machine on Earth, so massively complex and inextricably linked to human involvement and endeavor that it has alternately (and appropriately) been called an ecosystem."[2]

In fact, the US National Academy of Engineering has called electrification made possible by the grid "the most significant engineering achievement of the 20th Century."[3]

In the US, the grid as we know it today began taking shape in the early 1900s, when the 4,000-plus utility companies in operation at the time started laying down transmission and distribution lines to connect their local generation facilities to area homes and businesses.[4]

Over time, these local systems started to connect with one another to make it easier and



1. Western Interconnection | 2. Eastern Interconnection | 3. Texas Interconnection

Figure 1: The three major US electric interconnections (Source: US Energy Information Administration)

Introduction to the grid today

more cost-effective to meet growing energy demands.

Such interconnections allowed utilities to share costs when building new power plants, keeping electricity more affordable for customers. They also reduced the need for individual utility firms to overbuild generation facilities; extreme but infrequent spikes in demand could be met by tapping into a wider network rather than relying solely on local plants.

Today, these interconnections have evolved into two large-scale grids that serve the US' contiguous 48 states: the Eastern Interconnection and the Western Interconnection.

A smaller-scale, but still significant, grid—the Texas Interconnection—completes the bulk of the nation's energy infrastructure.[5]

Together, these systems comprise more than 3,200 utilities, 10,000-plus generating facilities, well over 100,000 miles of transmission lines and millions of miles of distribution lines.

While they aren't yet a fully national grid (as each interconnection can, for the most part, serve only customers in its own network), a project called Tres Amigas is under way to link all three major interconnections within the next several years.[6] ■

[1] "The Smart Grid: An Introduction" (US Department of Energy/Litos Strategic Communication, 2008, www.oe.energy.gov/SmartGridIntroduction.htm)
[2] Ibid.
[3] Ibid.
[4] US Energy Information Agency's Energy in Brief (www.eia.gov/energy_in_brief/power_grid.cfm)
[5] Ibid.
[6] Tres Amigas LLC (www.tresamigasllc.com). Date Viewed: 30/03/2011

The problem

While the power grid has served us well for more than a century, the aging infrastructure is having an increasingly hard time keeping up with society's rising need for electricity. Energy demand has grown along with population and an expanding economy, not to mention the rapid proliferation of electronic devices in homes and businesses.[7]

The type of energy we've long relied on also poses challenges for the existing grid. Coal, gas and nuclear power can be generated around the clock, with "peaker" plants available on standby to fire up quickly if demand exceeds baseline needs. But as concerns about climate change, carbon emissions and resource limitations have come to the fore, there's been an effort to expand the use of cleaner, renewable energy sources like wind and solar.

These green energy supplies cannot be ramped up or turned down as easily as fossil fuels; without a connection to a large-scale energy storage facility, they flow only when the sun shines and when the wind blows.

Years of declining investment in grid improvements have also contributed to the problem. Since 2000, for example, the US

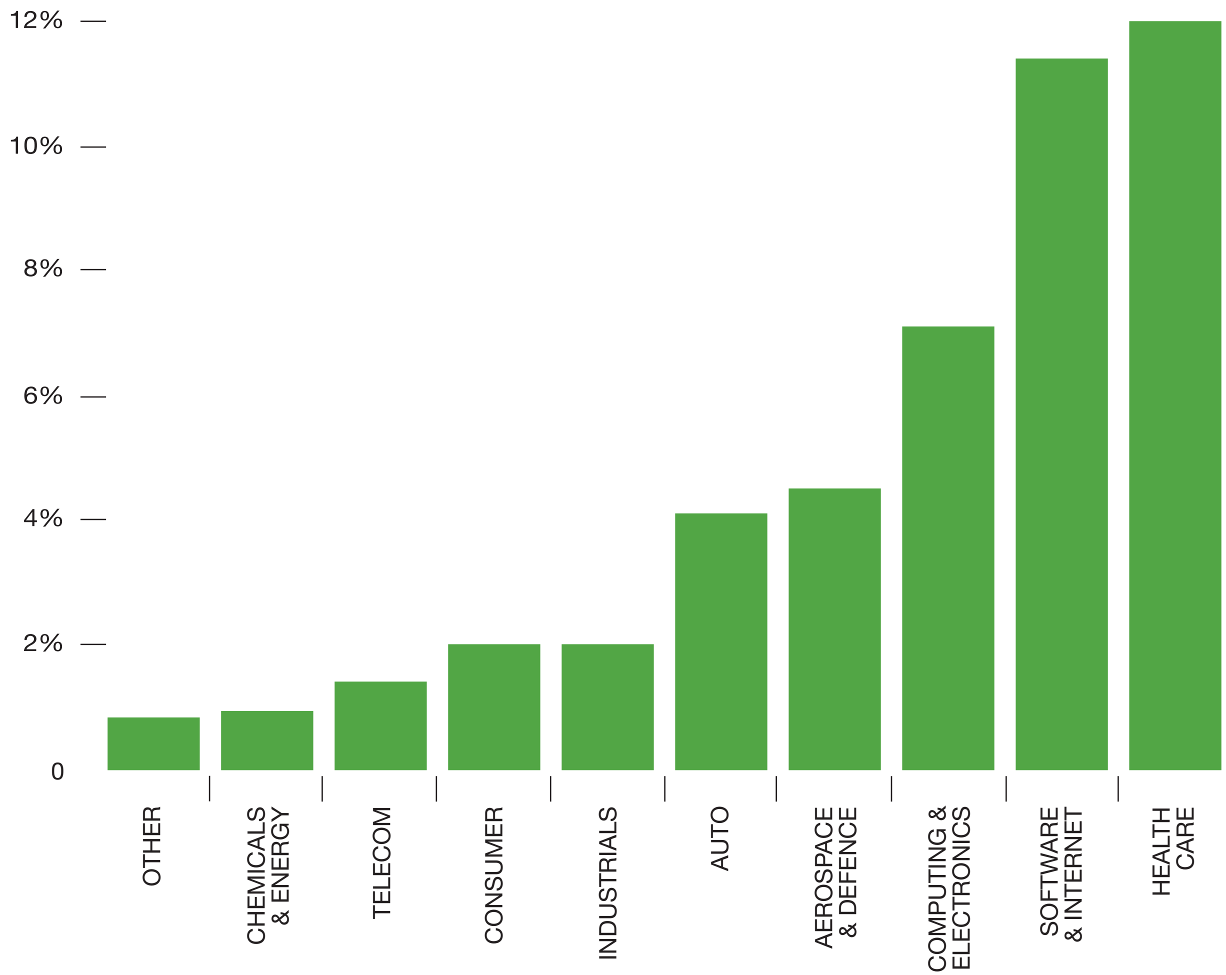


Figure 2: R&D spending as a percentage of revenues (Source: Booz & Company)

The problem

has added just 668 new miles of interstate transmission lines. This shortfall of spending, coupled with rising demand and management issues, have left today's grid vulnerable to disruptions, failure and even deliberate attacks. As a result, our energy infrastructure has started to suffer from a growing number of significant service interruptions and outages.

"Starting in 1995, the amortization and depreciation rate has exceeded utility construction expenditures," writes S. Massoud Amin, a professor of electrical engineering and director of the Technological Leadership Institute at the University of Minnesota. "In other words, for the past 15 years, utilities have harvested more than they have planted. The result is an increasingly stressed grid. Indeed, grid operators should be praised for keeping the lights on, while managing a system with diminished shock absorbers."[8]

Of the five major blackouts that have hit the US in the past 40 years, three have occurred in the past decade. Every year, service disruptions cost the economy around $150 billion a year—money that could be much better used for improving infrastructure and reviving the sputtering economy.[9]

While slow response times of legacy mechanical switches can be blamed for some of these failures, another problem is a dearth of data: not enough information to provide visibility and "situational awareness" about what is happening on different parts of the grid, and a lack of automated analytics. For instance, many utility firms must still wait until a customer calls in to discover that an outage has occurred.

Meanwhile, long-established electricity rate caps are being lifted in many areas, raising the cost of power for consumers. All these factors—aging infrastructure, the addition of renewables, lack of investment and disappearing rate caps—combine to point to the need for a better, more resilient, more data-aware and more automated grid. In other words, a smart grid. ■

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[7] "IEA expects energy use by new electronic devices to triple by 2030 but sees considerable room for more efficiency" (International Energy Agency, May 2009, www.iea.org/press/pressdetail.asp?PRESS_REL_ID=284)
[8] "US Electrical Grid Gets Less Reliable" (S. Massoud Amin, IEEE Spectrum, Jan. 2011, spectrum.ieee.org/energy/policy/us-electrical-grid-gets-less-reliable)
[9] "The Smart Grid: An Introduction" (US Department of Energy/Litos Strategic Communication, 2008, www.oe.energy.gov/SmartGridIntroduction.htm)

The answer: a smart grid

Let us start with a definition of the smart grid: it is a real-time, automated system for managing energy demands and responses for optimal efficiency.

So why are utilities, transmission network operators, distribution network operators and other sectors with a hand in operating the grid now moving to make our energy infrastructure smarter and more efficient?

Several factors are driving this transition:

- Legislation—A growing number of wide-ranging (such as the European Union's) and regional (California's, for example) legislative efforts have been adopted in the past decade to reduce carbon emissions in an effort to prevent dangerous climate change. These are putting pressure on energy firms to cut their dependence upon fossil fuels.

- Competitive advantage—In competitive environments, energy companies that can control infrastructure costs while providing a service that is more reliable and more resilient will be more appealing to customers. Similarly, municipal operators with smarter grids stand to make their communities more attractive

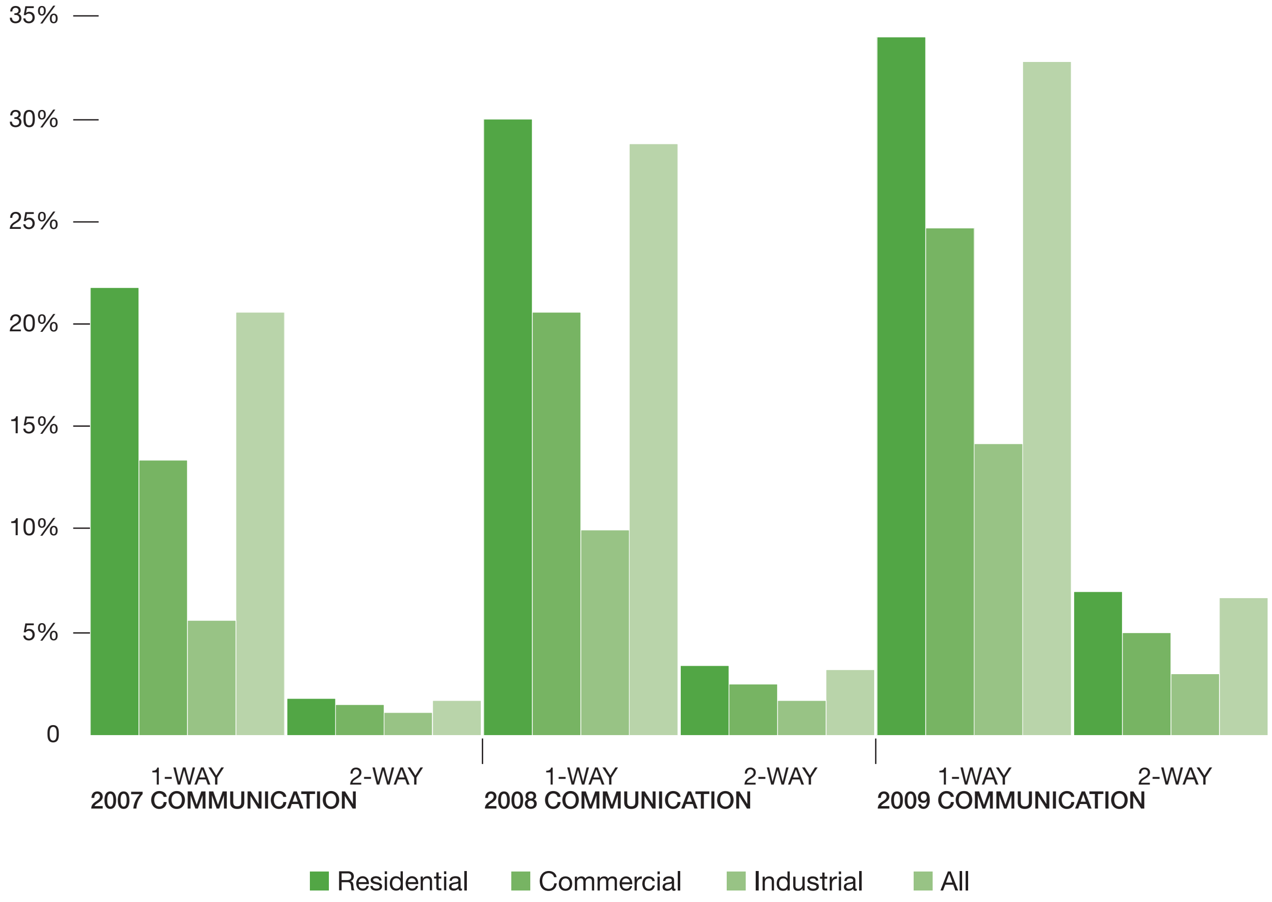

Figure 3: AMI deployments by users (Source: US Energy Information Administration)

The answer: a smart grid

to businesses, industries and individuals alike.

- Business opportunities—While electricity itself is a commodity, utilities that implement smart-grid technologies have the opportunity to create new products and services that can differentiate them from competitors, provide new revenue streams or reduce spending. These offerings could range from electricity pre-pay plans and iPhone consumer apps for remote energy management to time-of-use pricing and home security services.

- Resource constraints and need to reduce waste—In many regions, domestic supplies of coal and natural gas—the two fossil fuels most commonly used to generate electricity —are in decline, requiring imports from sources located farther away. These imports, in turn, can be disrupted by geopolitical troubles, natural disasters and oil price shocks that can impact fuel delivery systems. With the size of global oil reserves in question and indications that production might soon, or has already, peaked, the less dependent energy companies are upon a petroleum-based economy, the greater their chances of survival in future.

For many, the first technology that comes to mind when discussing the smart grid is advanced metering infrastructure (AMI). Popularly known as "smart meters," these devices are being deployed in homes, businesses and industries in many parts of the world to provide real- or near-real-time information about on-site energy consumption and costs.

Often described as a first step in the transition to a smart grid, AMI provides one- or two-way communications between energy users and utilities about electricity usage levels, patterns and trends. Integrated with smart appliances like programmable thermostats, water heaters and dishwashers, AMI can be used to "tell" devices when to switch on and off to reduce energy consumption during times of peak demand, or when to take advantage of lower off-peak prices.

The number of smart meters and other sensors is exploding globally, with "a billion transistors for every human," according to IBM.[10]

Increasingly large numbers of other "smart" devices are being rolled out to monitor key points on transmission and distribution networks, from transformers to wind farms, to small-scale generation and energy storage technologies at homes and businesses. All together, these devices will produce huge amounts of data with potential value… but only if the analytics tools for unlocking that value are in place first. ■

[10] "On a smarter planet, answers are hidden in the data" (IBM, No. 2 in the series, "Building a Smarter Planet.")

Why use analytics?

Analytics are important because data without context does not make for actionable intelligence. It is only when raw data are correlated to the sensors and other instruments that generated them, are assembled into a big-picture image of what is happening across the network, or are broken down to provide insights into how the different elements of the grid interact… it is only then that these numbers can offer guidance for the best responses from utilities, grid operators or other users.

Analytics tools that can process the consumption data coming in from an array of smart meters, for example, can help identify when demand might begin to put too much pressure on the generation end. Acted upon, this type of intelligence can help a utility company know when to begin shedding load or fire up peaker plants to avoid brownouts and blackouts.

A smart grid, for example, might have spared a large portion of the northeast US and Canada from the massive blackout in 2003[11] that affected some 55 million people. The power failure, ultimately blamed in part on FirstEnergy's not recognizing "the deteriorating condition of its system" on a hot August afternoon, led to a series of cascading failures that took out electricity across a much larger region. A resilient and self-healing grid monitored with analytics tools could have identified such threats earlier on, allowing utilities to take preventive measures.

Longer-term analyses of grid data can provide more detailed pictures of seasonal and annual changes in both generation and demand. These, in turn, can be used to model future demand and generation trends, which can help a utility better plan for capital expenditures (new power plants, wind farms or solar arrays) or more aggressive efficiency and demand-management policies to delay or prevent the need for the construction of new facilities.

Basing decisions on real-time data can ensure that actions and reactions are based on reality rather than on assumptions, intuitive responses and best guesses. With the exponential increases in data that utilities and energy companies can expect to see from the smart grid, analytics are the best way to make certain that *all* meaningful data are taken into account and insights are not lost in a sea of bits and bytes.

Businesses in general are already reporting significant benefits from their use of analytics. In a survey of 3,000 executives, managers and analysts conducted by the MIT Sloan Management Review and the IBM Institute for Business Value, analytics were found to be used five times more often by top-performing companies than by lower-performing ones.[12]

The survey illustrated the pressures organizations are feeling from the proliferation of data, with six out of 10 respondents agreeing that their workplace has "more data than it knows how to use effectively." ■

[11] "Interim Report on the August 14, 2003 Blackout" (New York Independent System Operator. January 8, 2004, www.hks.harvard.edu/hepg/Papers/NYISO.blackout.report.8.Jan.04.pdf)
[12] "Analytics: The new path to value" (IBM Institute for Business Value/MIT Sloan Management Review, 2010)

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As an IT leader in its own right, as well as a technology services company that integrates its offerings with numerous complementary partners around the globe, IBM comes to the smart-grid space with both micro (IT-generated data) and macro (systems and services integration) expertise.

IBM's ground-breaking capabilities in analytics were recently demonstrated by its Watson[13] system's victory over a real-life human champion on the Jeopardy! game show. With Watson, IBM shows it is possible for an advanced computing system with sophisticated analytics to "understand" complex conceptual questions (as opposed to formulaic problems) and to generate accurate responses both quickly and consistently.

IBM has also clarified and put a focus on what it says will be *the* issue facing organizations of every stripe in coming years: "big data," that is, flows of information "so large they define a new category."[14]

These two factors—advanced analytics and big data—are clearly a neat fit for the smart grid. With its hundreds of thousands, if not millions, of nodes (smart meters, transformers, grid-connected uninterruptible power supplies, etc.), the fully smart grid will prove to be possibly one of the biggest examples of "big data" in action. And given the critical nature of the system being analyzed—the energy infrastructure that drives our entire society—nowhere will advanced analytics be more important than in development of the smart grid.

With its market-leading visibility in the smart-cities space,[15] IBM is already putting advanced analytics to work for energy companies in many parts of the world. Working with Shanghai Electric Power Company, for example, it rolled out an Integrated Distribution Outage Planner (IDOP) in 2010 that is helping the utility reduce both the frequency and duration of electricity blackouts as it upgrades its infrastructure. The system enables Shanghai Power to integrate and analyze data from various relevant departments to get better insights into service areas with the potential for power outages, and to improve the scheduling of maintenance tasks to reduce the chance of service disruptions.

Since the IDOP system was implemented, Shanghai Power has increased its monthly electricity revenues by 35 million yuan ($5.1 million). It has also cut the amount of time it spends each month on coordinating scheduled power outages from a half-month to a matter of days.[16]

IBM's analytics offerings run the gamut, from analytics-focused data warehousing solutions to InfoSphere BigInsights, which combines a host of IBM capabilities into a single, business-ready platform.

These offerings include:

- Cognos 10 software for business intelligence. This software lets users sift through massive amounts of data, in any combination and

[13] IBM—Watson (www-03.ibm.com/innovation/us/watson/index.html)
[14] IBM—Big Data (www-01.ibm.com/software/data/infosphere/hadoop/)
[15] "The Greenbang Smart Matrix™ –Smart Cities: How brands compare on marketing vs. capability in the smart-city space" (Greenbang, www.greenbang.com/commerce/Reports/Smart-Matrix-a-Smart-Cities/prod_18.html)
[16] "IBM and Shanghai Electric Power to Pilot New Smart Grid" (IBM, 4 Nov. 2010, www-03.ibm.com/press/us/en/pressrelease/32926.wss)

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covering any time-frame, to generate custom reports for decision-making, filter information to generate various "what-if" scenarios, create visualizations of key performance indicators and produce reality-based budgets and forecasts.

- SPSS software for data-gathering, statistical analysis, modeling and information-driven deployment decisions. The SPSS Modeler application, for instance, uses data mining to generate graphics that can make resource planning and risk issues easier to visualize. It also enables users to generate predictions by testing different hypotheses and deploying models based on historic data and data trends.

- Intelligent Utility Network Communications Services for reducing communications costs in smart-grid projects. These solutions allow utilities to analyze data to assess smart-grid communications technologies, develop implementation roadmaps, test plans and manage security, administration and maintenance issues.

- Solution Architecture for Energy and Utilities Framework for smart-grid monitoring. Utilities can use analytics to monitor networks for unusual usage patterns or a sudden cutoff in meter readings that could indicate a security breach. Anticipating, responding to and preventing such breaches can help companies avoid the costs—financial and otherwise—associated with security intrusions.

- ILOG CPLEX Optimization Studio for solving modeling and application challenges in planning and scheduling tasks.

For example, researchers at the University of Southampton's School of Electronics and Computer Science have used ILOG CPLEX optimization to study what impact smart meters coupled with home-based energy storage could have on consumption habits… and have reached some unexpected conclusions by doing so.

The researchers used the software to test various scenarios looking at the meters' effects on electricity consumption, energy cost savings, off-peak energy use and demand peaks, and found the result was an average energy cost savings of 13 percent. Not only did that make up for the expense of purchasing a 4kWh home-based energy storage system, they found, but the benefits in overall consumption reduction would also carry over to residents without home-based energy storage in the form of lower electricity prices.

The optimization software also indicated that a home energy-storage adoption rate of just 38 percent was all it would take to maximize the benefits for consumers across society.

Already a brand leader in smart cities, IBM has both the breadth and depth of capabilities to capture the smart-grid analytics space as well. ■

Conclusion

Managing the vast flow of data that will be generated every second by tomorrow's smart grid is critical for extracting the maximum benefits from an upgraded energy infrastructure. The solutions will lie with analytics tools that can capture a holistic view of the entire power network for intelligent decision-making, planning, problem-solving and forecasting.

In short, the smart grid won't be nearly so smart without the analytics that can make sense of all the data it generates. ■

Resources:
Greenbang (www.greenbang.com)
IBM (www.ibm.com)
IEEE Spectrum (spectrum.ieee.org)
International Energy Agency (www.iea.org)
Tres Amigas LLC (www.tresamigasllc.com)
US Department of Energy Office of Electricity Delivery & Energy Reliability (www.oe.energy.gov)
US Energy Information Agency (www.eia.gov)

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