Jesse Berst

SMART GRID 101

Everything you always wanted to know about grid modernization in 5 easy lessons

SMART GRID™ NEWS.COM

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Acknowledgment

Every new industry needs its pathfinders and pioneers. From the beginning, Accenture has been at the forefront of the smart grid. The company has completed more than 100 smart grid projects in more than 20 countries. Its Utilities Group includes 10,000 professionals working with approximately 275 clients in 40 countries, including 93% of the utilities on the 2010 Global Fortune 500 list.

In addition, Accenture has invested to help improve things for everyone. It belongs to many of the most important associations, including the GridWise Alliance and the Smart Grid Consumer Collaborative. And it has financed and shared some vitally important research, including reports on lessons learned from early pilots and seminal studies of consumer preferences.

We thank Accenture for its support of the industry and of this publication.

— Jesse Berst

Foreword

By Jesse Berst

What an exciting time in the world of energy. We are reinventing electricity!

- How we make it
- How we use it
- What we use it for
- How we deliver it

It's that last piece that's often overlooked... even though the smart grid is the key to all the others. A smart grid is essential to get renewable energy from where it is made (remote wind farms, for instance) to where it is needed (urban areas). Only a smart grid can cope with the variability and counterbalance the constant fluctuations of wind and solar.

A smart grid is essential to energy efficiency as well. First, it's the best way to make the system itself more efficient (the wires, substations and other devices) so we lose less power the moving around. Second, it allows us to connect smart buildings to the grid. When that connection is made,

buildings can listen for signals from the grid that tell them where and how to fine tune their energy used to minimize their power bill.stations and other devices) so we lose less power the moving around. Second, it allows us to connect smart buildings to the grid. When that connection is made, buildings can listen for signals from the grid that tell them where and how to fine tune their energy used to minimize their power bill.

Essential to energy independence and prosperity

And a smart grid is essential to achieve independence from fossil fuels via electric transportation. Someday we will have it ends up millions of electric vehicles on our roads. Those vehicles will need the ability to recharge at any time and any place. Only a smart grid can manage that enormous task while keeping everything in balance (and while keeping costs as low as possible).

There are many more things that could be said about the value and importance of the smart grid. To our national defense. To our energy security. To our environment, because of smart grid means fewer power plants and fewer power lines. A smart grid squeezes far more out of our existing system.

Winners and losers

A smart grid is also important to our global competitiveness. The world has entered the Electricity Economy. In the last century, national prosperity was predicated on access to cheap petroleum. In this century, it will

depend on access to cheap, clean electricity.That is why it is so important that every company and every consumer understand enough about the smart grid to advocate for its construction in their part of the world. For the smart grid is arising all around the planet. It is springing up in parts of North America. It is emerging in sections of Latin America and Australasia. And it is racing forward in China.

Those regions that do it right – that build a modernized grid without overspending – will gain an economic advantage. The smart grid is essential infrastructure. It is every bit as important to a region as roads, trains and telecommunications. With it, a region can lift itself to a new level of prosperity powered by clean, cheap, abundant electricity. Without it, a region will be at an economic and environmental disadvantage.

We hope this introduction has given you a glimpse of the smart grid's importance and why it has been the focus of so much public and private funding and attention. We hope the short and simple document that follows will give you a quick but comprehensive overview of the smart grid and a peek into your future.

— Jesse Berst is Founding Editor and Chief Analyst at Smart Grid News

Chapter 1

Electricity Ecosystem

The electric power industry is one of the largest and most capital-intensive industries on earth. In the U.S. alone, its total asset value is more than $800 billion and annual sales are more than $300 billion, according to the U.S. Department of Energy. It is broadly divided into three segments: Generation, Delivery, and End Use.

It starts with generation

Electricity is created by converting other energy sources — for instance coal, natural gas, nuclear, hydro or renewables such as wind and geothermal. There are roughly 10,000 central power plants scattered across the U.S. that generate the bulk of the electricity. An additional 5,600 distributed generation facilities provide smaller amounts of power, typically for backup or for combined heat and power (also called co-gen). Coal-burning plants, under fire for their greenhouse gas emissions, remain the predominant source of electricity generation in the U.S. They produce roughly 50% of all U.S. electricity, followed by natural gas and nuclear with roughly 20% each.

Next comes delivery

The delivery segment is like an electricity highway that transports power from the point of generation to the point of use. Roughly 200,000 miles of transmission lines move bulk power at high voltages from generating stations to substations where the power is stepped down to medium voltages. The distribution system delivers power to end users and also handles metering, billing, and other functions associated with power sales to end users.

Then comes end use

Rapidly changing customer needs for electricity are one of the biggest challenges facing the electric power industry. Eventually, though, every part of the electric power value chain will be digitally monitored and managed. There will be visibility and control all the way from generation through every section of the grid all the way down to individual devices in factories, offices and homes.

Chapter 2

Traditional Grid

The power grid is the infrastructure that transports electricity from where it is made — coal plants or hydroelectric dams, for instance — to the homes, businesses and industries where it's consumed. For many of us, the most visible components of the grid are the towering high-voltage transmission lines that crisscross the countryside or the neighborhood substations that distribute power locally.

How it works

The traditional grid is based on design requirements written in the 1950s, when the primary objective was to keep the lights on. This approach to electric power involves large, centralized power plants that feed power over an electro-mechanical grid. In this producer-controlled model, power flows in one direction only. There is no two-way communication that allows interactivity between end users and the grid.

In the last 30 years, we have seen a complete overhaul of the telecommunications network. We have also seen the creation of many other digital networks, including cellular, GPS, cable, satellite TV and, of course, the

It is only in the last few years that the electric power infrastructure has started its own digital makeover.

Internet. As a result, those networks can often be managed, diagnosed and even repaired remotely.

By contrast, it is only in the last few years that the electric power infrastructure has started its own digital makeover. It is still largely analog and electromechanical.

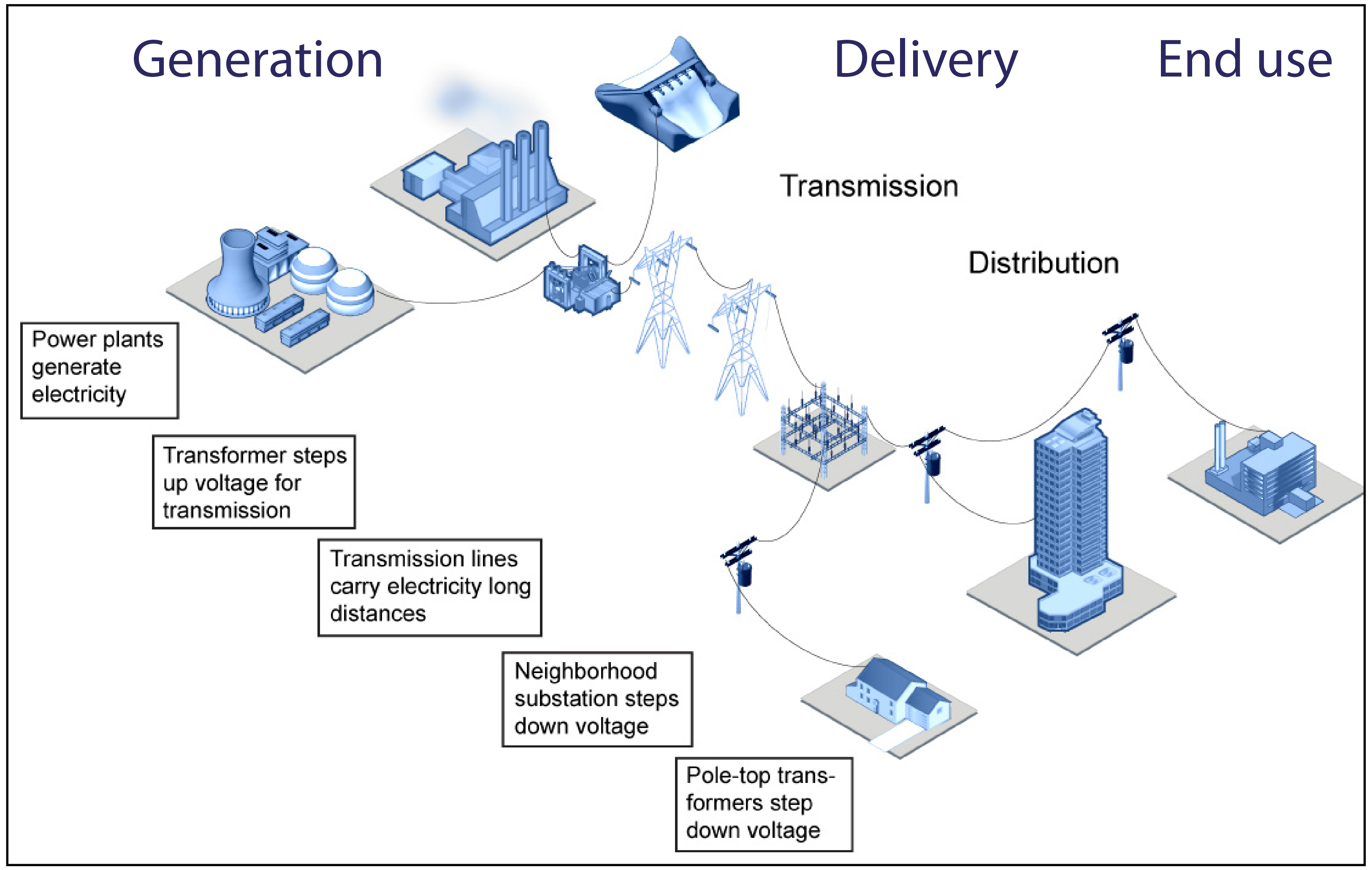


Figure 1. The grid performs the central delivery function. High-voltage wires and substations that transport power long distances are known collectively as the transmission system. Medium-voltage wires and substations that move power locally are known as the distribution system.

The challenges

As the supply and demand for electricity has skyrocketed through the computer revolution, growth of the Internet, and proliferation of electronic devices, there has been no significant investment in the transmission and distribution infrastructure that connects the two. At a time when 60% of the U.S. gross domestic product depends directly on electricity (compared to 20% in 1950), we rely on an electric power infrastructure that is aging and outmoded.

Did you know?

Electricity demand growth has slowed in each decade since the 1950s. After 9.8-percent annual growth in the 1950s, demand (including retail sales and direct use) increased 2.4 percent per year in the 1990s. From 2000 to 2009 (including the 2008-2009 economic downturn) demand grew by 0.5 percent per year. In the Energy Information Administration's Annual Energy Outlook 2011 (AEO2011) Reference case, electricity demand growth rebounds but remains relatively slow, as growing demand for electricity services is offset by efficiency gains from new appliance standards and investments in energy-efficient equipment.

- Source: U.S. Energy Information Administration, released April 26, 2011

Chapter 3

Smart Grid

At the beginning of the century, a new concept emerged in how electricity is managed. Under this model, the grid becomes less of a one-way highway and more of an integrated, interactive network. Many smaller power plants are distributed throughout this network, including renewable energy generation. And most importantly, this new grid gains "intelligence" and two-way communications.

How it works

Like so many other digital networks, the Smart Grid consists of three basic pieces:

- Smart devices
- Two-way communications
- Advanced software

Smart devices such as meters, monitors and intelligent electronic devices gather information about the flow and condition of power, and about the condition of equipment.

A Smart Grid is less of a grid and more of an intelligent , interactive network.

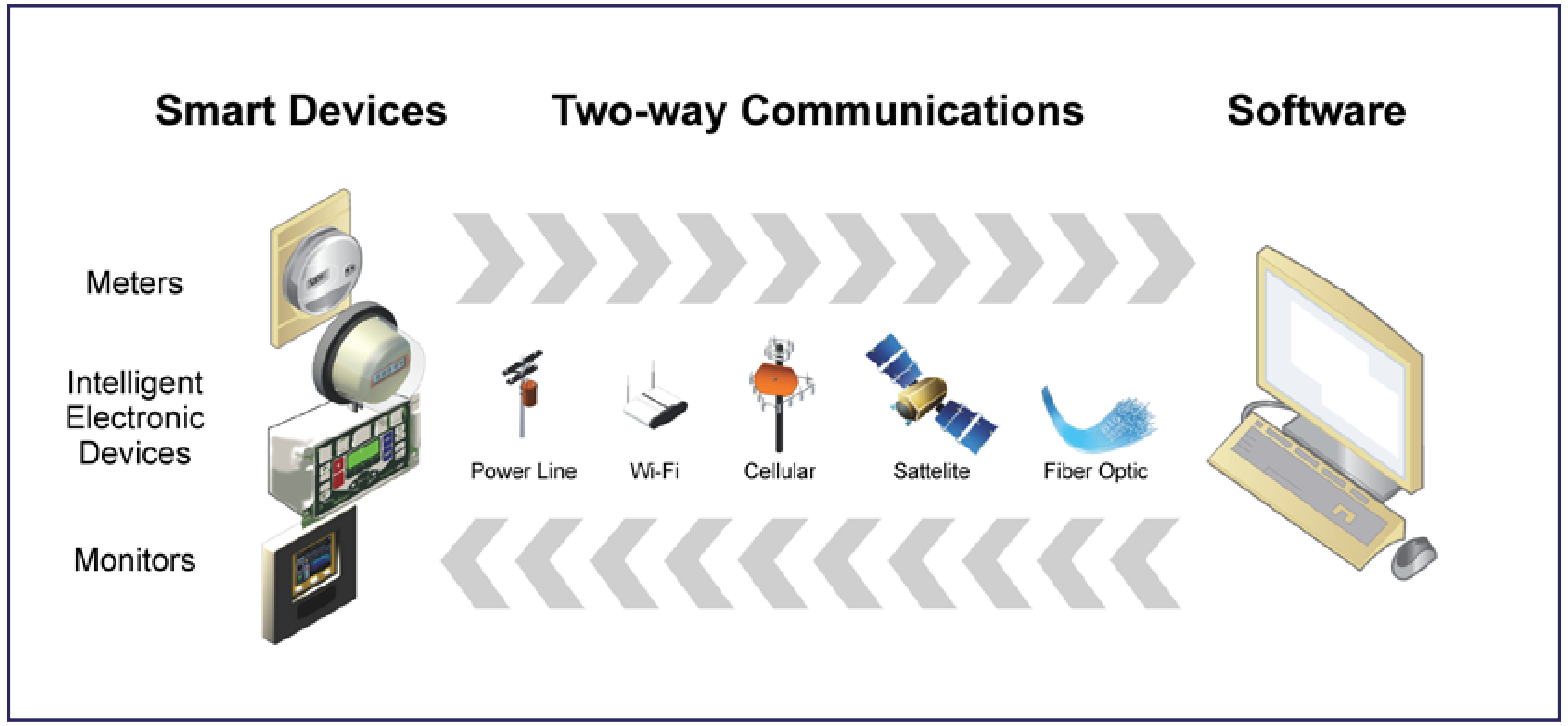


Figure 3-1: Smart devices, two-way communication and advanced software are essential components of the modern grid.

The smart devices transmit the information over a two-way communications pathway. In Europe, many systems use powerline communications, which broadcast over the electric power lines themselves. In the U.S., radio frequency (RF) communications are more common, typically systems that resemble the Wi-Fi networks used for personal computers. And many systems are hybrids, incorporating cellular, satellite, fiber-optic or other forms. Regardless of the specific technologies, the goal is to give every part of the system the ability to talk and to listen.

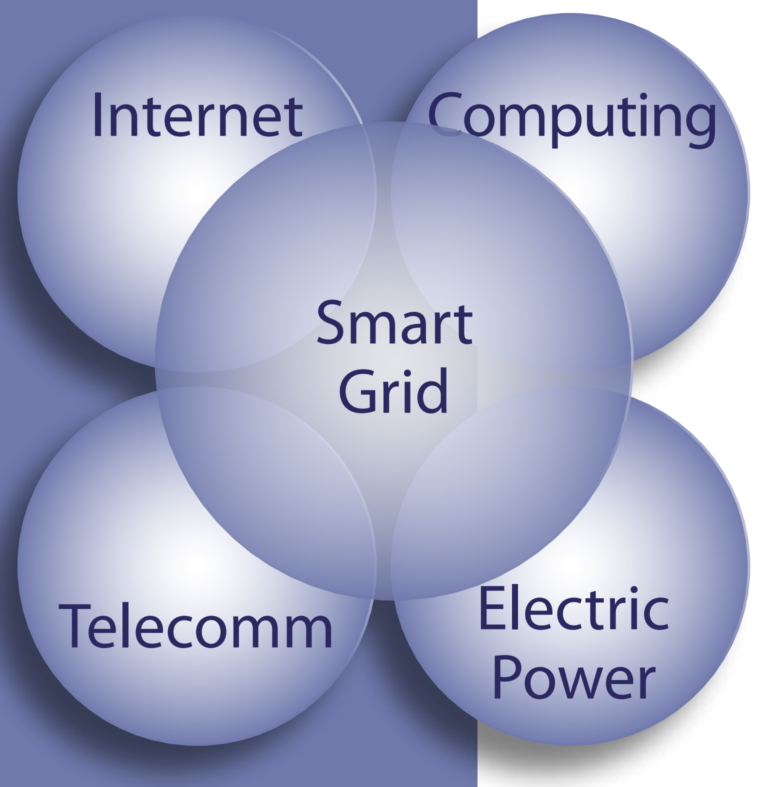


Figure 3-2: The Smart Grid is a convergence of technologies from several industries.

Advanced software processes the data and uses it to power applications. Some of those applications help run the grid itself. Others handle billing, service and other customer-facing activities.

The smart devices measure and monitor what is going on. They send that information over the communications system, to other devices and to the control center. Advanced software gathers and analyzes data from all those devices, then uses the information to create powerful applications.

What makes the new grid smart is a convergence of advanced technologies. Concepts proven in telecommunications, computing, and the Internet are combining with ideas from the electric power industry to allow things that were too difficult or too expensive 10 years ago.

The Smart Grid is equipped end-to-end with sensors and switches that can monitor, report back, and accept commands. Thanks to real-time information, system operators will be able to predict, diagnose and mitigate issues that might previously have caused an outage or blackout. End users will have more control over their energy consumption and costs.

The challenges

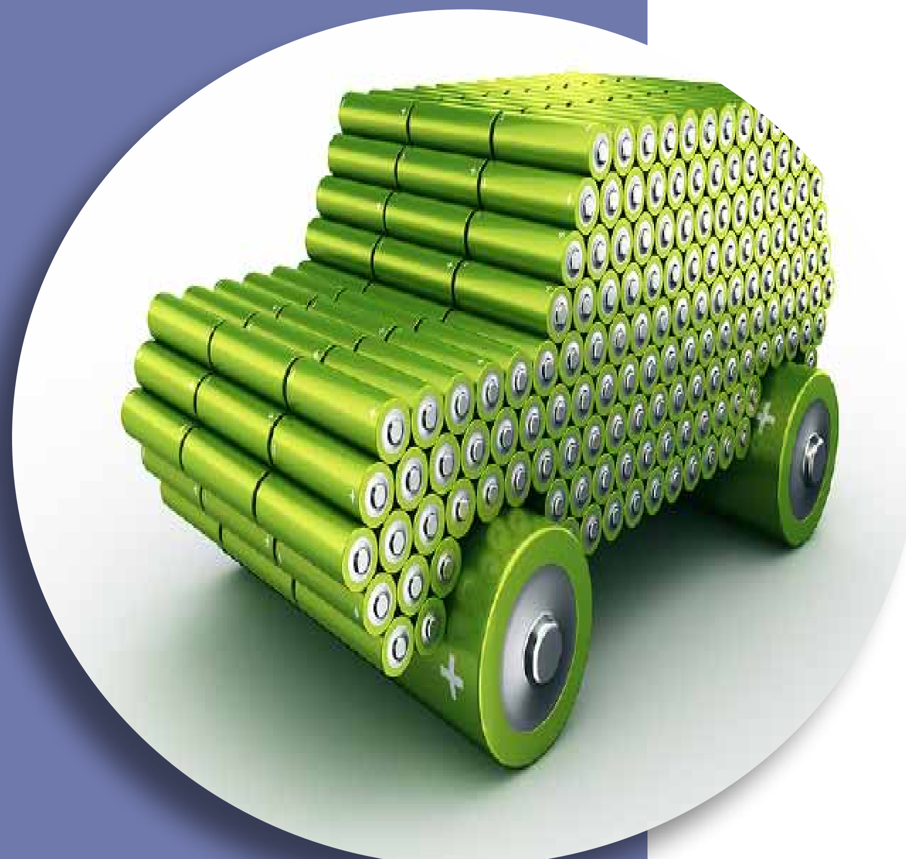
After years of indifference, policymakers and public opinion leaders have now jumped onto the Smart Grid bandwagon, recognizing its importance to prosperity and national security. But no single entity owns, operates or regulates the electric grid. There are more than 3,100 public or privately owned utilities and cooperatives that distribute power, another 2,000+

non-utility companies that produce, market and/or transmit power, plus armies of regulators and policy makers at many levels of government — all of whom share a role in the interconnectivity and overall vitality of their "piece" of the grid.

Did you know?

Folk singer Woody Guthrie spent one month in 1941 working for the federal government. His job was to travel to the Pacific Northwest and write songs promoting huge hydroelectric dams on the Columbia River. The government faced powerful opposition from private utilities and hoped that folk songs would prompt more public support. Out of this month of work came some of Guthrie's best-known songs, including *Roll on Columbia,* which he wrote after seeing the Bonneville Dam some 40 miles east of Portland, Oregon. (Source: NPR)

Roll on, Columbia, roll on.
Roll on, Columbia, roll on.
Your power is turning our darkness to dawn,
So, roll on, Columbia, roll on



Chapter 4

Forces in Favor

Some predict that worldwide electric power generation may nearly double between 2004 and 2030. And as the world moves from a Petroleum Economy to an Electricity Economy over the next 30 years, electricity will become our most strategic commodity.

Yet the electric grid — the all-important "middleware" that ties the generation of electrical power to its end use — suffers from years of neglect and deferred maintenance. Simply patching yesterday's outmoded infrastructure isn't the answer.

How it works

Increasingly the world is looking to the electric power industry for solutions to our looming energy crises:

- *Climate change?* Generate more power from renewable energy.
- *Declining oil production?* Electrify our transportation system.
- *Rising costs?* Become ultra-efficient.
- *Economic disaster if the grid fails?* Make it impervious to attack and natural disasters.

In the
next 30 years,
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Industry experts believe a modern, digitized Smart Grid can help solve some of our most pressing energy woes — connecting more renewable energy to the grid, providing an infrastructure to support electric vehicles, enabling energy efficiency, and using advanced technologies to create a resilient "self-healing" grid.

Earlier we discussed the three "pieces" of the electricity ecosystem: 1) Generation, 2) Delivery and 3) End Use. Each piece contributes forces in favor of the Smart Grid. It is the confluence of all of these market drivers that makes grid modernization such an inevitable trend.

Generation drivers

The generation side of the electric power value chain is being impelled by two major trends: 1) diversity of supply and 2) air and water neutrality.

Diversity of supply summarizes a variety of changes now rippling through the system. Some of those changes refer to how electricity is generated, such as alternative energy and renewable energy. Some of the changes refer to substitutes to generation, such as demand response and energy storage. And some of the changes refer to where the energy source is located, such as distributed generation and distributed resources.

Air and water neutrality encapsulates the urgent need to generate and consume electricity to preserve the environment. This world is moving to limits on carbon emissions. Going forward, the water/power nexus will also gain attention. The next decade will bring a violent collision between

End use is pushed by by population, inflation of expectations, and the electrification of everything.

competing uses for water: consumption, agriculture, power generation, recreation and environmental preservation.

End use drivers

The end use side of the equation is being pushed by three macro forces: 1) the population explosion, 2) the inflation of expectations, and 3) the electrification of everything.

The population explosion refers to the number of people needing electricity. The world passed 6 billion inhabitants in 2000. As of December 2008, the figure stood at 6.7 billion according to the U.S. Census Bureau.

The inflation of expectations refers to changing demographic trends. The developing world is rapidly catching up to the electricity-hungry lifestyle of the industrialized world.

The electrification of everything refers to the increasing dominance of electricity as the preferred form of energy. Several developments have driven electricity into every facet of our lives, most notably motors, microprocessors and microwaves. And now another massive change is about to begin: the switch to electric transportation.

This triple multiplier — more kinds of electrical devices pursued by more people wanting more of them — is behind the projected increases in demand. The U.S. Energy Information Administration (EIA) predicts that

The billions in Recovery Act dollars being spent to forge a new energy economy is just a down payment.

worldwide electric power generation will nearly double between 2004 and 2030.

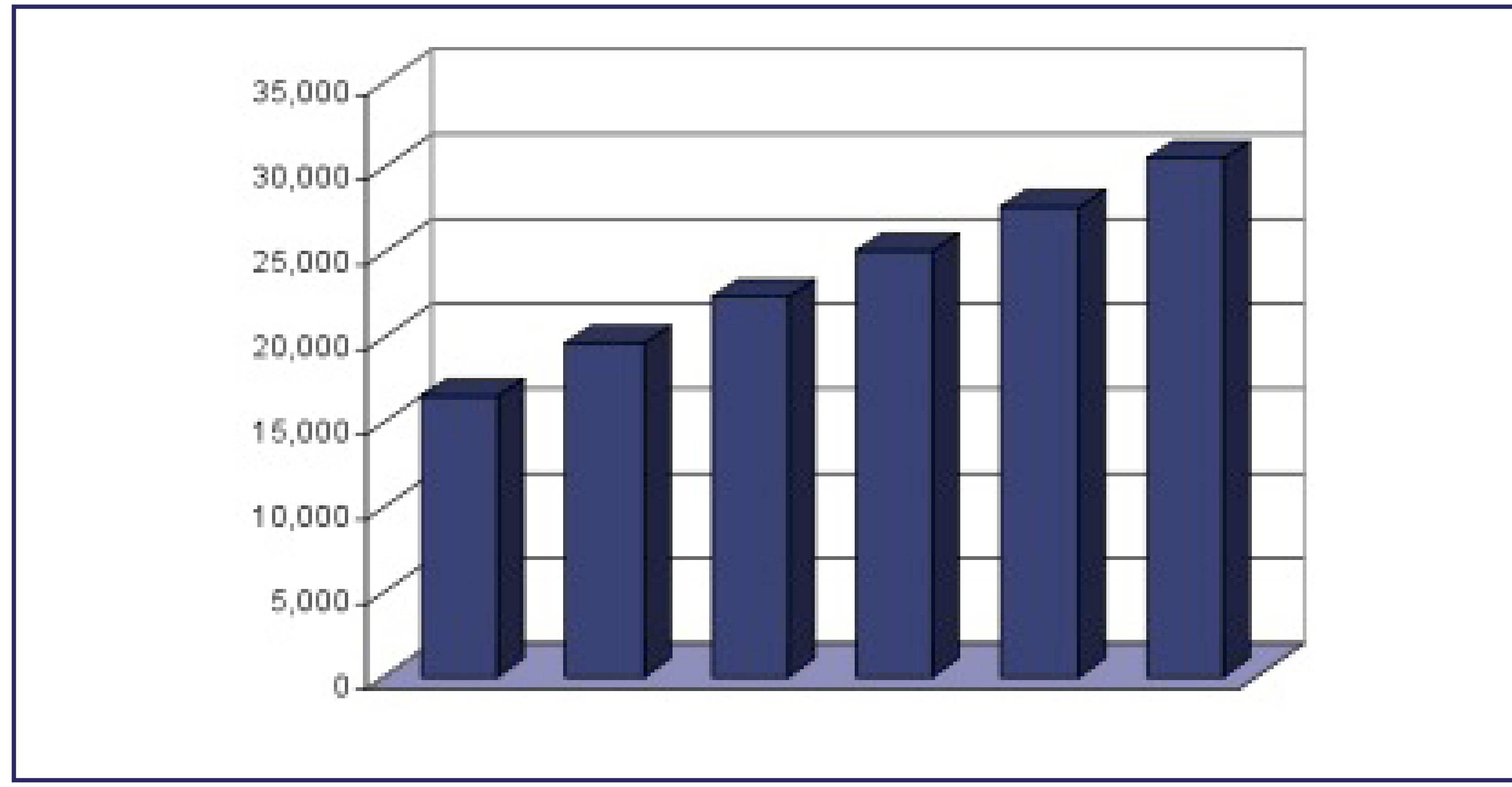

Figure 4-1: Power generation will nearly double from 2004 to 2030. (Energy Information Administration, 2006)

The challenges

The Obama Administration's push to promote clean energy and reduce the nation's dependence on foreign oil has led to a huge investment in renewable energy, energy efficiency, electric transportation, and modernization of the electric grid. But even the billions in Recovery Act dollars being spent to forge a new energy economy is just a down payment.

Estimates of what it will cost for a full upgrade of the grid range wildly. The elephant in the room is our aging transmission system. Harbor Research estimated back in 2005 that 60% of North America's grid infrastructure would require replacement by 2020. The Brattle Group puts the price tag to meet mandates for integrating more renewable energy onto the existing electric grid at $50 to $100 billion.

Did you know?

There are an estimated 3,200-plus traditional electric utilities in the United States. Of those, about 210 are Investor-Owned Utilities (IOUs), which are for-profit corporations that are traded on stock exchanges. IOUs are regulated by state public utility commissions.

The vast majority of utilities are Publicly Owned Utilities (POUs), which are not-for-profit public entities. These include municipal utilities, which are operated by a single city government. Utilities run by a group of cities (or a county) are public utility districts (PUDs). And those owned by their customers are cooperatives. PUDs and coops are typically found in smaller and more rural communities.

Inconsistent dergulation of the power industry has limited competition and stifled innovation.

Chapter 5

Barriers

Despite the many forces pushing the world towards grid modernization, barriers remain.

Costs

Although it typically pays for itself in a few years, grid modernization certainly costs more than doing nothing at all. Many developed nations are struggling to pay for renewal of all of their major infrastructure, whether roads, bridges, airports, water systems or grids. Many developing nations have financial challenges. And virtually all nations were severely hampered by the global recession that came to a head in 2008.

Regulatory barriers

Many parts of the world regulate electric power through policies originally developed during the Great Depression of the 1930s. Although appropriate for those times, many of those regulations are now outmoded. Unlike the airline and phone industries, electric power has not deregulated in a consistent way, which has limited competition and stifled innovation.

What's worse, Europe and the United States are both patchworks of inconsistent regulatory policy. In the U.S., each state and territory has its own public utility commission that sets rates and policies, creating enormous variation from region to region. Utilities whose territories go across jurisdictional boundaries often have to gain rate approvals from multiple utility commissions and regulatory bodies. And to do so, they often have to adopt completely different rate approaches and program structures, which can slow projects by months or even years.

Lack of open standards

The Internet could not have arisen without HTML, Internet Protocol and other open standards. Likewise, the Smart Grid needs consistent standards worldwide.

Many of those standards are in development now in various places around the world. Completing them, stabilizing them and normalizing them planet-wide is a process that will take years of additional development, testing and negotiation.

Chapter 6

Terms & Resources

A subset of terms that may be helpful in better understanding Smart Grid concepts appears below. For a more extensive glossary, please visit SmartGridNews.com.

- Advanced metering infrastructure (AMI): This refers to all of the components of the infrastructure relating to electric metering and communications, including "smart meters" capable of two-way communication.
- Alternative energy: A vague term that usually refers to non-conventional sources, including fuel cells, waste-to-energy and renewables other than hydro.
- Biomass: A renewable fuel source for power generation that includes wood and wood waste, municipal solid waste, crops and biogas.
- Command and control: Utilities have control centers that are able to monitor and manage the smart grid, providing remote diagnosis, and remote repair in some instances.
- Demand response: Cutting demand instead of increasing supply. Typically refers to programs that aggregate small reductions from many different users and then present that reduction to the system as a block of power.

- Distribution automation (DA): DA and substation automation improve reliability with real-time monitoring and intelligent control. Many analysts believe it is the secret to making the smart grid pay for itself.
- Distributed generation: Smaller sources of generation scattered throughout the system and located closer to the end user (as opposed to large centralized generation)
- Distribution: Medium-voltage distribution lines move power from substations to the customer premise, where it is stepped down to lower voltages (typically 220v or 110v).
- Electric vehicle (EV): Originally the term referred to vehicles that operate exclusively on electric power. More recently, the term describes the entire family of vehicles that use electricity as a power source including plug-in hybrid electric vehicles (PHEV) and battery electric vehicles (BEV).
- Energy storage: Storing energy for later use via batteries, capacitors, compressed air, flywheels, fuel cells or pumped storage. Typically, the use of this term implies storage large enough to have an impact on the grid.
- Generation: Converting energy into electricity, typically in large central facilities. Roughly 95% of all U.S. electricity is generated in centralized plants. In the U.S., coal is the most common fuel, followed by natural gas and nuclear.

- Power marketing: Power is often earmarked for a particular utility. In other cases, it is marketed to other utilities or to large industrial users and wheeled (transmitted) over the grid. Power from privately owned plants is sold through power marketers. Power from federally owned hydroelectric dams is allocated through power agencies.
- Real-time pricing: As opposed to fixed pricing, this refers to charging electricity consumers varying rates to reflect power cost fluctuations occurring over time.
- Renewable energy: Energy from sustainable, non-fossil sources such as wind, solar, geothermal, marine and hydro.
- Sensor: Sensors report on conditions or send an alert when conditions go outside specified boundaries. They are used to monitor many conditions: temperature, line sag, transformer condition, physical security, equipment condition and many others. They are an integral component of a smart grid.
- Standards: Critical to the industry, codified and administered standards ensure reliability, efficiency, and interoperability. Typically administered by government entities such as FERC and state PUCs.
- Storage: A general term for a variety of power storage technologies, including pumped storage, fuel cells, batteries, flywheels, and more.
- Transmission: High-voltage transmission lines move power from generating plants to substations, where the voltage is stepped down for distribution.

Resources

SmartGridNews.com

- Smart grid technologies
- Smart grid projects
- Smart grid key players
- Smart grid videos

Government sites

- Smartgrid.gov: What is the smart grid?
- Energy.gov: The smart grid - an introduction
- Smart grid information clearinghouse

Nonprofits

- Galvin Electricity Initiative
- Smart Grid Consumer Collaborative
- GridWise Alliance


If you innovate,
they will come.
In a recent Accenture survey, 89% of executives agreed that innovation is as important as cost management for high performance. But while many organizations are investing more in innovation, only a few have a rigorous approach for managing the process. As a result, even innovative organizations often fail to realize the benefits that their new ideas could produce. To see how our vast experience and research can help you embark upon your smart grid journey, visit accenture.com
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