John D. McDonald

the next-generation grid

energy infrastructure of the future

THE THEME OF THIS ISSUE IS "the next-generation grid," the same as PSCE 2009. We will discuss the electrical infrastructure of the future and what we will need to do to support a strong and growing economy in a sustainable and environmentally sensitive manner.

What worked in the past will not work anymore. Old grid structures need to be updated. New grid structures are being built at record paces. The strain on resources, fuel, siting, building, and maintenance is overwhelming. Things are changing! Global power requirements are more intense, both from a capacity and quality standpoint. Digital-quality power represents 10% of the total U.S. electrical load and is expected to reach 30% by 2020. The country is rapidly entering a period in which significant and ongoing new investment in electricity capacity will be required to keep supply in line with demand, but we have constraints on siting and environmental impacts. New technologies and a higher standard of living have produced changes in the way citizens consume electricity. As residents build larger homes, plug in computers, and install flat-screen televisions, the overall electricity demand increases.

With global energy consumption forecasted to triple by 2050, the situation is not going to get easier. Power generation currently accounts for 40% of the U.S. carbon footprint. We, as a world, must find a way to do more with less, and quickly. Around the globe, the price of electricity is on the rise. For example, in the United States, a 9.8% increase in electric bills is forecasted for 2009, compared with an increase of 2.2% in 2007 and a projected average increase of about 5.2% in 2008. Texas electricity prices increased more than 55% from 2002 to 2006. Maryland electricity consumers received a 90% price hike from 2005 to 2007, while Delaware was a close second with an 86% price rise. Rapidly increasing delivered fuel costs for power generation, particularly for natural gas, are pushing up electricity prices.

As a result of the stress and strain, power outages are all too common, affecting everyday life and creating global inconveniences. Curtailments caused by outages in Korea resulted in US$16 million to US$18 million in lost sales for one company. The rolling power outages that have become an unwelcome fact of life amount to a "national emergency" in South Africa. A 20-min power interruption at a chip fabrication plant is estimated to cost US$30 million. An interruption at a financial data center can cost US$10 million per minute. Surely, the distribution grid requires new technology to increase generation flexibility.

As the great French writer Victor Hugo said, "Nothing in the world is as powerful as an idea whose time has come." Electricity is poised to change the world again. Electricity is central to our lives and our livelihood. Demand is growing rapidly. Outages are becoming costlier and, due to aging assets, more likely. Green environmental concerns have reached mainstream society. It is when great challenges loom that innovation is able to flourish.

Today's electric grid is inefficient. Losses occur throughout the generation and delivery process and at the site of use.

- ✔ In the United States and Mexico, electric utilities and end-users install more than 1 million distribution transformers each year. If all of these distribution transformers used high-efficiency amorphous core technology rather than high-efficiency silicon steel, the annual electricity savings would be approximately 750 million kWh. These energy savings could avoid more than 465,000 tons of carbon dioxide emissions from traditional U.S. electricity sources, which is equivalent to the impact of removing nearly 90,000 cars from U.S. roads for one year.
- ✔ Demand response programs have great potential. If U.S. utilities with peak demand greater than 3,000 MW achieved top-quartile performance for demand-side management, more than 47 GW of generation could be avoided, along with 106 million tons of carbon dioxide emissions per year. Similarly, consumers, when properly incented, can reduce peak demand by more than 15% and total demand by more than 10%.

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Government support will be required to accelerate and enable the growth in renewables. As noted earlier, energy consumption could triple by 2050, and a diversified energy portfolio will be required to meet those energy needs. This portfolio will include renewable sources, such as wind, solar, and biogas. Today, renewables represent about 1% of energy globally, but this number is expected to double every three years.

As we think about the energy infrastructure of the future, we see more complexity. Consumer needs will demand reinvestment in the distribution grid. As a society, we must become more educated on the complexities introduced to our electrical power grid by the integration of such things as renewables, distributed generation, demand response programs, and plug-in vehicles. The

Join Us in Seattle for PSCE 2009!

The final details of the third IEEE Power & Energy Society (PES) Power System Conference and Exposition (PSCE) are in place. This year's event, to be held in Seattle, Washington, 15–18 March 2009, is shaping up to far exceed expectations with a comprehensive technical program comprising paper and panel sessions, a poster session and reception, technical tours, and a short course and tutorials awarding continuing education units (CEUs), as well as a student program, social events, networking opportunities, and a wide variety of companion activities. PSCE 2009 will bring together an international group of power systems engineers, operators, planners, policymakers, economists, academics, and others with an interest in the following topics:

- system-wide events and analysis methods
- integrating wind energy
- emerging software needs for the restructured grid
- control system robustness today and in the future
- the smart grid and the Internet.

The exposition will feature more than 75 exhibitors showcasing state-of-the-art software and hardware systems, as well as consulting services for those involved with power systems. In addition, there will be times devoted exclusively to the exhibits—with no parallel technical sessions scheduled—so attendees can focus on the displays and have a chance to speak directly with vendors about the latest technologies.

benefits of these components are key in increasing energy productivity (as worldwide energy consumption is expected to triple by 2050) and power reliability (power outages and quality disruptions currently cost U.S. businesses US$100 billion or more per year) and in decreasing the environmental footprint of the electric generation sector (which currently accounts for about 40% of U.S. carbon dioxide emissions). All of these components are creating a more dynamic and integrated network, but our power grid was not originally designed with this future in mind. The management and optimization of these elements will require a smarter power grid.

Smart-grid technologies allow conservation without compromise, reducing power disturbances by more than 80% and saving customers in excess of US$50 billion while enabling increased productivity. Smart-grid implementation can slash the total U.S. output of carbon emissions by up to 25%. This equates to the carbon dioxide benefits of planting up to 160 million acres of forest and the nitrogen oxide benefits of removing up to 130 million cars from the road.

The smart grid is about consumer choice. Currently, consumers have no line of sight into their energy spend and usage. Their bills are a reflection of estimated usage. Smart-grid technologies change this situation by providing customers with valuable information and data. These technologies should not change consumers' daily lives in an obvious or intrusive way but rather empower consumers with this new knowledge and information. Consumers are given the opportunity to alter their behavior or opt into programs to better manage their energy use and spending. Consumers can lower their energy costs and carbon footprint.

The smart grid is a journey, not a single destination. To support this change, we need to align incentives that

- ✔ encourage city-scale deployments demonstrating technology and benefits
- ✔ change old paradigms and reward conservation instead of demand growth.

We recognize that to be sustainable, ecology must make economic sense. In the U.S. vernacular: "Being green must equate to making green." The right incentive systems are required. For many industries, there is a direct correlation between improving efficiency and improving the bottom line. It is different for most electric utilities, and they need help from regulators—in the form of incentives—to drive the right behavior. The largest, most cost-effective opportunity for electric utilities is to reduce consumer demand, but this is not in the interest of all utilities. Utilities earn revenue based on consumption, not conservation. This must change: All utilities must be incentivized to promote energy efficiency within their networks. Decoupling—cutting the direct tie between sales and profits—is one option to alter the scenario, and California has demonstrated great leadership in this regard. The state's decoupling policy is partially credited for making California the nation's most energy-efficient state while promoting economic growth. Under decoupling, California's per capita energy use has remained relatively flat over the last 30 years. In comparison, per capita energy consumption in the rest of the country has increased by 50%.

In This Issue

We invite you to read this special issue of thought-provoking articles to appreciate the different perspectives on the next-generation grid. The first article is by Jay Giri, David Sun, and Rene Avila-Rosales from AREVA T&D and is titled "Wanted: A More Intelligent Grid." They discuss the advent of phasor measurement unit (PMU)-based applications using fast, synchronized PMU data to develop new tools to improve grid reliability. As they declare, the development of new PMU-based applications to enhance grid reliability is limited only by our creativity and innovation. PSCE Super Session 1 on systemwide events and analysis methods will cover many of the same topics as this article does.

In the next article, "A Mighty Wind" by J. Charles Smith, Robert Thresher, Robert Zavadil, Edgar DeMeo, Richard Piwko, Bernhard Ernst, and Thomas Ackermann, the authors emphasize that a significant increase in the penetration of wind power will not be realized without a correspondingly significant increase in the expansion of the electric transmission infrastructure. They also discuss a number of new approaches and creative solutions that are being explored now that the problem has been recognized. Europeans are leading the way with sophisticated operational capabilities and experience, and others can take advantage of their experience to realize higher penetration of renewables, including wind energy. PSCE Super Session 2 on integrating wind energy will cover resource planning, forecasting, system operations issues, transmission access, and dynamic simulation, all of which are discussed by the authors in their article.

The article titled "Grid of the Future," by Ali Ipakchi and Farrokh Albuyeh, stresses that the changes to the power system resulting from the next-generation grid present the power industry with the biggest challenge it has ever faced. Will we experience distribution system congestion? Will we require the equivalent of transmission reservation and scheduling (the open access same-time information system (OASIS), interchange distribution calculator (IDC), and E-tagging) and the use of locational pricing to manage the loading of distribution facilities? With the implementation of a smart-grid information technology (IT) system, the utility's organizational "silos" of information must be integrated. This article deals with many of the topics that will be covered by PSCE Super Session 3 on emerging software needs for the restructured grid.

In their article titled "The Evolution of Distribution," Jiyuan Fan and Stuart Borlase from GE Energy T&D discuss the development of new technologies and applications in distribution management to drive optimization of the distribution grid and assets. The challenges include seamless integration of the smart-grid technologies and development under the new environment of clean energy, distributed generation, and end-user smart energy consumption. The authors explain the functionality of current distribution management systems (DMSs) and contrast it with the functionality needed by future

(continued on page 94)

guest editorial *(continued from page 32)*

advanced DMSs. This article covers the topics of supervisory control and data acquisition (SCADA)/DMS and planning, operation, and control.

The concept of the smart grid is not universally defined, but it is clear that the general concept requires a multipronged research and engineering effort, explain Mladen Kezunovic, Gerald T. Heydt, Christopher DeMarco, and Timothy Mount in their article titled "Is Teamwork the Smart Solution?." The authors describe how a university consortium—a collaborative effort among many universities that, in this case, utilizes industry and scientific inputs to tackle the grand challenges of power engineering—is conducting research in the areas of transmission engineering, distribution engineering, systems engineering, and markets and finance. The article summarizes some of the research directions undertaken within the Power Systems Engineering Research Center (PSERC), which was formed by the National Science Foundation and a group of 13 universities and about 40 industry sponsors.

Within the PES, there is increased emphasis on the next-generation grid. Four years ago, the Wind Power Coordinating Committee was established to promote and coordinate PES efforts within the Technical Council. Similarly, two years ago, the Intelligent Grid Coordinating Committee was established to coordinate the various efforts regarding the next-generation grid, both within and outside the PES. I encourage you to get involved in these groups and to participate in their meetings and in the technical sessions they organize for PES conferences and meetings. p&e

book reviews *(continued from page 84)*

be a great addition to the book. Installed wide-area stability controls are mainly based on direct detection of selected outages. These emergency controls are termed system Integrity protection schemes (SIPS), also referred to as special protection systems (SPSs) or remedial actions schemes (RASs) (see the September/October 2008 P&E issue of this magazine).

In summary, the book is a very comprehensive reference tool; the bibliographical references are handy. The readers can benefit more from examples with step-by-step solutions that can be followed through to conclusion. A discussion on use of different models to improve damping performance will be beneficial to the readers. A chapter on various control methodologies beyond traditional computational approaches will be a great addition.

Reviewed by Vahid Madani

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calendar *(continued from page 86)*

October 2009

T&D Asia, 27–30 October, COEX Exhibition Center, Seoul, Korea, contact Young-Hyun Moon, Professor, Dept. of Electrical Engineering, Yonsei University, 131 Shinchon-Dong, Seodaemun-Ku, Seoul 120-749, +82 2 2123 2771, fax +82 2 2123 7722, moon@yonsei.ac.kr.

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T&D Conference and Exposition, 20–22 April, Morial Convention Center, New Orleans, Louisiana, USA, contact Tommy Mayne, 30523 Woodland Dr., Lacombe, LA 70445, +1 504 427 3390, fax +1 985 882 8059, t.w.mayne@ieee.org, http://www.ieeet-d.org/ (sponsored by PES). p&e