The Power Delivery System of the Future

Electric Power Research Institute (EPRI) Briefing Paper
Presented by Clark W. Gellings, Vice President, Power Delivery & Markets
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Briefing: The Electrical Grid and The Blackout of 2003:
Explanations & Solutions

The recent blackout in the Northeast reminds us that electricity is indeed essential to our well-being. And it highlights one of the most fundamental of electric functions: getting electricity from the point of generation to the point of use. Power delivery has been part of the utility industry for so long that it is hard to imagine that this process has not already been optimized. However, the power delivery function is changing and growing more complex with the exciting requirements of the digital economy, the onset of competitive power markets, the implementation of modern and self-generation, and the saturation of existing transmission and distribution capacity. Without accelerated investment and careful policy analysis, the vulnerabilities already present in today's power system will continue to degrade.

Simply stated, today's electricity infrastructure is inadequate to meet rising consumer needs and expectations.

The Vision

The envisioned power delivery system and electricity markets will enable achievement of the following goals:

- Physical and information assets that are protected from man-made and natural threats, and a power delivery infrastructure that can be quickly restored in the event of attack or a disruption: a "self-healing grid".
- Extremely reliable delivery of the high quality "digital-grade" power needed by a growing number of critical electricity end-uses
- Availability of a wide range of "always-on, price-smart" electricity-related consumer and business services, including low-cost, high value energy services, that stimulate the economy and offer consumers greater control over energy usage and expenses
- Minimized environmental and societal impact by improving use of the existing infrastructure; promoting development, implementation, and use of energy efficient equipment and systems; and stimulating the development, implementation, and use of clean distributed energy resources and efficient combined heat and power technologies
- Improved productivity growth rates, increased economic growth rates, and decreased electricity intensity (ratio of electricity use to gross domestic product, GDP)

Barriers to Achieving this Vision

To achieve this vision of the power delivery system and electricity markets, accelerated public/private research, design, and development (RD&D), investment, and careful policy analysis are needed to overcome the following barriers and vulnerabilities:

- The existing power delivery infrastructure is vulnerable to human error, natural disasters, and intentional physical and cyber attack.
- Investment in expansion and maintenance of this infrastructure is lagging, while electricity demand grows and will continue to grow.
- This infrastructure is not being expanded or enhanced to meet the demands of wholesale competition in the electric power industry, and does not facilitate connectivity between consumers and markets.
- Under continued stress, the present infrastructure cannot support levels of power, security, quality, reliability, and availability (SQRA) needed for economic prosperity.
- The infrastructure does not adequately accommodate emerging beneficial technologies including distributed energy resources and energy storage, nor does it facilitate enormous business opportunities in retail electricity/information services.
- The present electric power delivery infrastructure was not designed to meet, and is unable to meet, the needs of a digital society – a society that relies on microprocessor-based devices in homes, offices, commercial buildings, industrial facilities, and vehicles.

Enabling Technologies

EPRI has developed the following list of critical enabling technologies that are needed to move toward realizing the vision of the power delivery infrastructure and electricity markets:

- Automation: the heart of a “smart power delivery system”
- Communication architecture: the foundation of the power delivery system of the future
- Distributed energy resources and storage development and integration
- Power electronics-based controllers
- Power market tools
- Technology innovation in electricity use

These technologies, are synergistic (i.e., they support realization of multiple aspects of the vision). Aspects of some of these enabling technologies are under development today. Each of these technologies calls for either continued emphasis or initiation of efforts soon in order to meet the energy needs of society in the next 20 years and beyond.

Automation. The Heart of a “Smart Power Delivery System”. Automation will play a key role in providing high levels of power SQRA throughout the electricity value chain of the near future. To a consumer, automation may mean receiving hourly electricity price signals, which can automatically adjust home thermostat settings via a smart consumer portal. To a distribution system operator, automation may mean automatic “islanding” of a distribution feeder with local distributed energy resources in an emergency. To a power system operator, automation means a self-healing, self-optimizing smart power delivery system that automatically anticipates and quickly responds to disturbances to minimize their impact, minimizing or eliminating power disruptions altogether. This smart power delivery system will also enable a revolution in consumer services via sophisticated retail markets. Through a two-way consumer portal that replaces today's electric meter, consumers will tie into this smart power delivery system. This will allow price signals, decisions, communications, and network intelligence to efficiently flow back and forth between consumer and service provider in real time. The resulting fully functioning retail marketplace will offer consumers a wide range of services, including premium power options, real-time power quality monitoring, home automation services, and much more.

Communication Architecture. To realize the vision of the smart power delivery system, standardized communications architecture must first be developed and overlaid on today's power delivery system. This "integrated energy and communications system architecture" (IECSA) will be an open standards-based systems architecture for a data communications and distributed computing infrastructure. Several technical elements will constitute this infrastructure including, but not limited to, data networking, communications over a wide variety of physical media, and embedded computing technologies. IECSA will enable the automated monitoring and control of power delivery systems in real time, support deployment of technologies that increase the control and capacity of power delivery systems, enhance the performance of end-use digital devices that consumers employ, and enable consumer connectivity, thereby revolutionizing the value of consumer services.

Distributed Energy Resources and Storage Development and Integration. Small power generation and storage devices distributed throughout – and seamlessly integrated with – the power delivery system ("distributed energy resources") and bulk storage technologies offer potential solutions to several challenges that the electric power industry currently faces. These challenges include the needs to strengthen the power delivery infrastructure, provide high quality power, facilitate provision of a range of services to consumers, and provide consumers lower cost, higher SQRA power. However, various impediments stand in the way of widespread realization of these benefits. A key challenge for distributed generation and storage technologies, for example, is to develop ways of seamlessly integrating these devices into the power delivery system, and then dispatching them so that they can contribute to overall reliability and power quality. Both distributed storage and bulk storage technologies address the inefficiencies inherent in the fact that, unlike other commodities, almost all electricity today must be used at the instant it is produced.

Power Electronics-Based Controllers. Power electronics-based controllers, based on solid-state devices, offer control of the power delivery system with the speed and accuracy of a microprocessor, but at a power level 500 million times higher. These controllers allow utilities and power system operators to direct power along specific corridors – meaning that the physical flow of power can be aligned with commercial power transactions. In many instances, power electronics-based controllers can increase power transfer capacity by up to 50 percent and, by eliminating power bottlenecks, extend the market reach of competitive power generation. On distribution systems, converter-based power electronics technology can also help solve power quality problems such as voltage sags, voltage flicker, and harmonics.

Power Market Tools. To accommodate changes in retail power markets worldwide, market-based mechanisms are needed that offer incentives to market participants in ways that benefit all stakeholders, facilitate efficient planning for expansion of the power delivery infrastructure, effectively allocate risk, and connect consumers to markets. For example, service providers need a new methodology for the design of retail service programs for electricity consumers. At the same time, consumers need help devising ways they can participate profitably in markets by providing dispatchable or curtailable electric loads, especially by providing reserves. And market participants critically need new ways to manage financial risk. To enable the efficient operation of both wholesale and retail markets, rapid, open access to data is essential. Hence, development of data and communications standards for emerging markets is needed. Further, to test the viability of various wholesale and retail power market design options before they are put into practice, power market simulation tools are needed to help stakeholders establish equitable power markets.

Technology Innovation in Electricity Use. Technology innovation in electricity use is a cornerstone of global economic progress. In the U.S., for example, the growth in GDP over the past 50 years has been accompanied by improvements in energy intensity and labor productivity. Improved energy-use efficiencies also provide environmental benefits. Development and adoption of technologies in the following areas are needed:

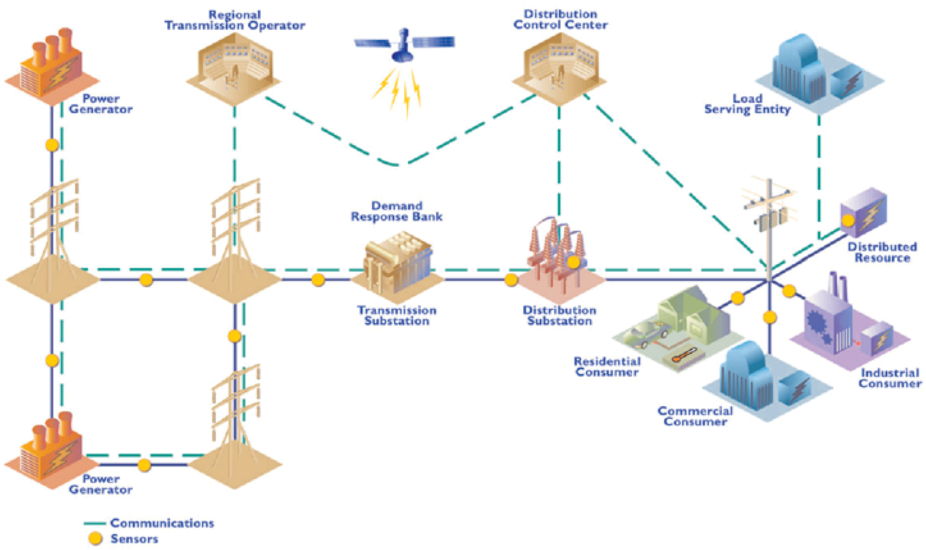
- Industrial electrotechnologies and motor systems
- Improvement in indoor air quality
- Advanced lighting
- Automated electronic equipment recycling processes

In addition, widespread use of electric transportation solutions – including hybrid and fuel cell vehicles – will reduce petroleum consumption, reduce the U.S. trade deficit, enhance U.S. GDP, reduce emissions, and provide other benefits.

Conclusion

EPRI invites the participation of energy companies, universities, government and regulatory agencies, technology companies, associations, public advocacy organizations, and other interested parties throughout the world in refining the vision and evolving the needed technology. Only through collaboration can the resources and commitment be marshaled to reach these destinations.

Integrated Electric and Communications Systems



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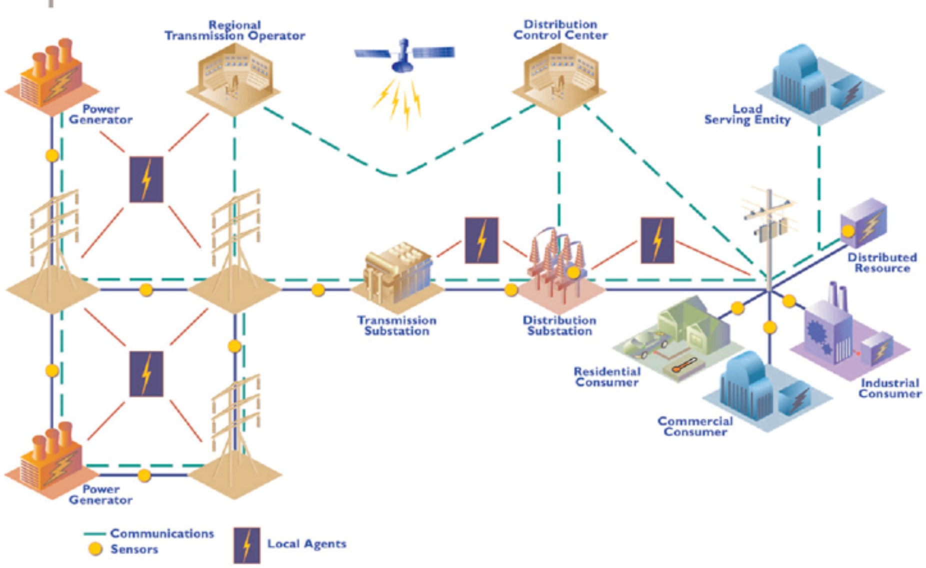
Deploy Local Computational Agents



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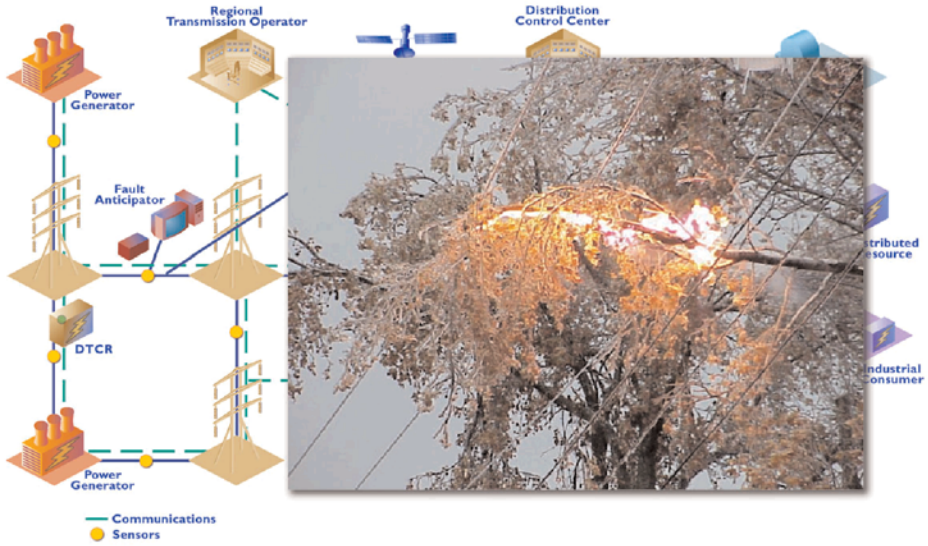
Apply Fault Anticipation



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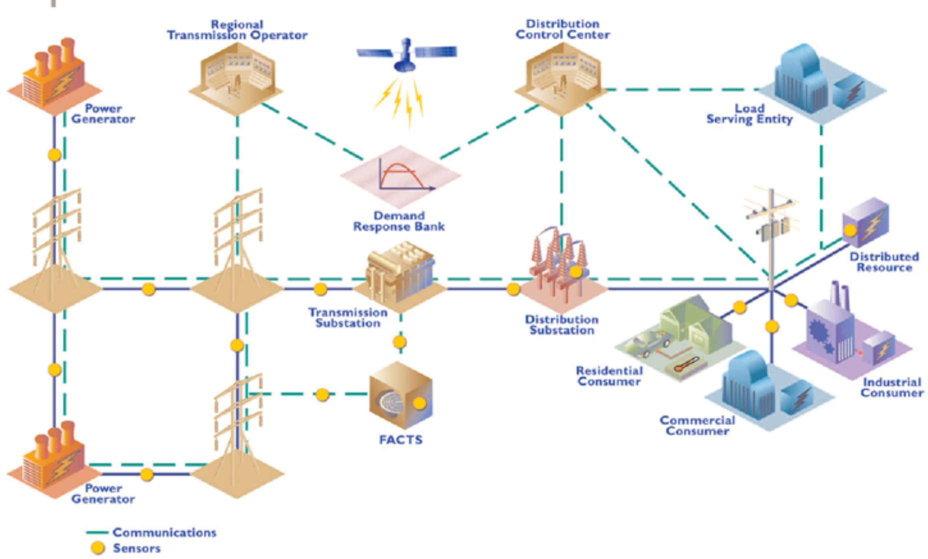
Apply Electronic Power Flow Control



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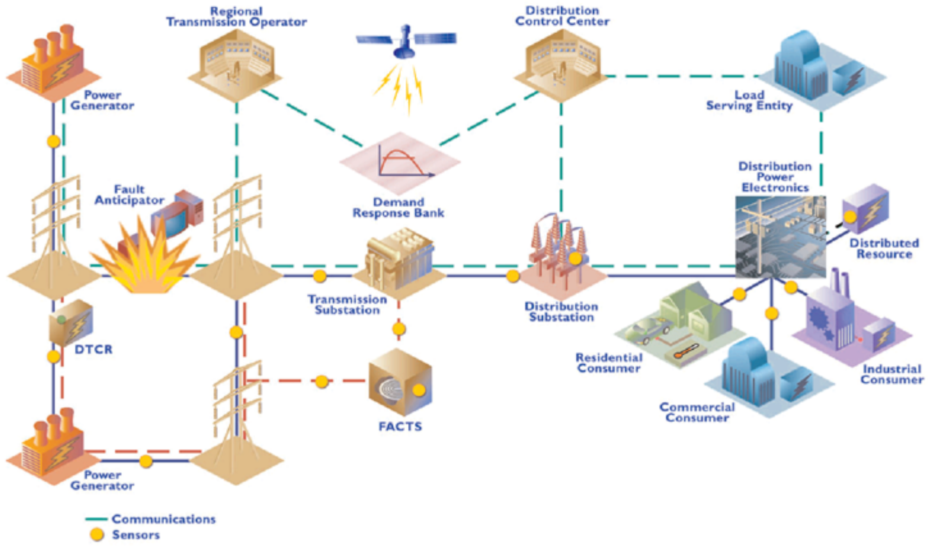
Enable A Self-Healing Power Delivery System



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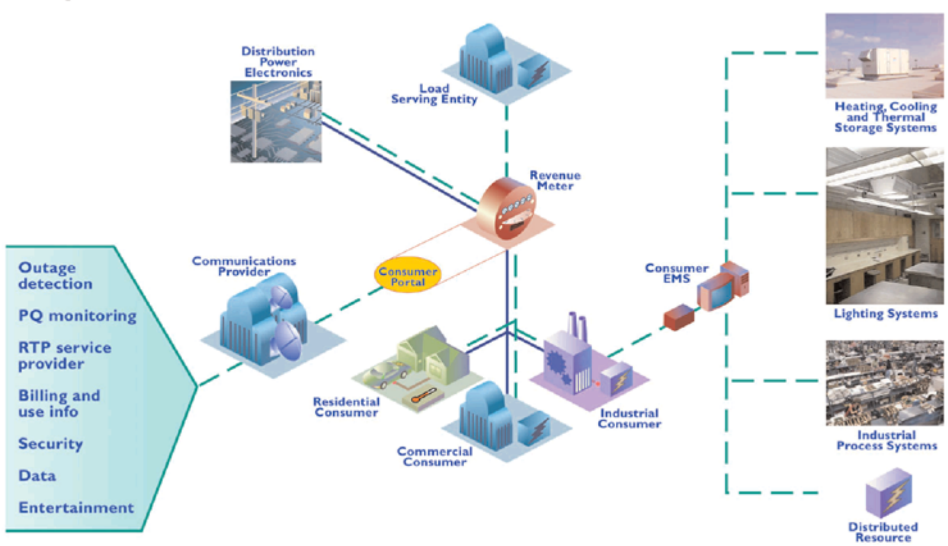
Consumer Portal



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