

SHAPING THE FUTURE

Innovative approaches to upcoming challenges



DC-Powered Data Centers

Demand is surging for Internet-related services, from digital video and music delivery to online gaming, web-page shopping, and Internet-based telephony. Internet companies serve this growing appetite with vast data centers, each of which might host thousands of servers and consume several megawatts of power. With energy consumption by data centers expected to double from 2006 levels by 2011, various options are being considered to improve the efficiency of these facilities.

One option is to power the centers with direct current (DC) rather than conventional alternating current (AC). EPRI has been investigating the advantages and drawbacks of this approach for a number of years and conducted one of the first demonstration projects in 2006. In addition to efficiency, advantages of a DC architecture include higher reliability, smaller footprint, and lower capital cost. Data center operators may actually be most interested in this method because it can allow them to achieve reliability approaching that of the telecom industry. Results of the demonstration and other work on DC data centers are available in an EPRI white paper (1020818) published earlier this year.

Avoiding Conversion Losses

Power entering a data center undergoes several AC/DC and DC/AC conversions as it passes through the facility's power-conditioning and uninterruptible power supply systems. In each conversion, energy is lost in the form of waste heat. By eliminating as many intermediate conversion stages as possible, DC architectures can improve efficiency, simplify the design of power supplies, and reduce the building's cooling requirements—a substantial issue for temperature-sensitive servers.

EPRI's 2006 demonstration, carried out in cooperation with the Lawrence Berkeley National Laboratory and other industry partners, compared a conventional AC architecture with two different DC configurations at a Sun Microsystems data center. The demonstration indicated that DC data centers would consume 7%–28% less power than conventional AC systems. Subsequent projects in the United States, Sweden, France, Japan, and South Korea have shown similar efficiency improvements.

By reducing power conversions, a DC facility can use simpler,

more compact circuit designs, and the number of circuit breakers may be cut by half. This reduction, combined with smaller cooling systems, can reduce the center's physical footprint significantly. An Intel study showed that a DC data center could occupy a third less space than a comparable AC configuration.

Also, with a DC power bus, DC data centers could directly integrate distributed energy resources such as photovoltaic arrays without concerns about synchronizing with the AC grid. Such tie-ins would allow opportunistic dispatch of renewables, reducing the amount of electricity that needed to be purchased from the grid during expensive peak demand periods and delivering lower operating costs. These setups could garner further savings through incentives such as renewable energy credits.



DC demonstration at a Sun Microsystems data center

Challenges for Further Research

Adopting DC data centers as a mainstream technology will require further research and testing, as well as new standards in a number of areas. Because DC current does not have a zero cross-

ing like AC current, it is more difficult to interrupt, and simple disconnection will cause arcing; new DC connectors that extinguish arcing during disconnects already have been developed to increase data center personnel safety.

Theoretically, the power quality impacts of DC architectures could be significantly lower than those of AC systems, since there are no harmonics and no power factor correction circuits. But this area remains to be investigated in detail, especially with regard to potential effects of cell phones and other radio-frequency transmitters, which could introduce disturbances onto the distribution network. DC bus faults and startup transients also may present problems, and appropriate grounding and over-current protection strategies need to be developed. EPRI is actively pursuing power quality research for DC facilities, beginning with system simulations to determine the impacts of such disturbances.

Interest in DC data center architectures is already spurring considerable work on new design, operation, and safety standards, as well as on training to ensure worker safety in this unfamiliar power distribution environment.

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Building the Framework for Demand Response-Ready Devices

Demand response (DR) remains relatively underutilized in the United States, despite its potential benefits to utilities, consumers, and society. According to the U.S. Federal Energy Regulatory Commission (FERC), demand response potential in the United States today is approximately 37 gigawatts (GW), which represents about 4.6% of the nation's summer peak demand of 810 GW. Most of today's capability derives from large businesses that participate in interruptible tariffs that obligate them to shed load at the request of their utility in return for a reduced electricity rate.

One barrier to greater demand response availability and participation is utilities' costs of installing equipment to enable load control and demand response, such as programmable communicating thermostats and sensors on air conditioners, appliances, water heaters, and other large end uses that contribute to peak demand. Also, most customers are reluctant to have unfamiliar controls installed in residences or businesses. However, such barriers could be overcome if energy-consuming appliances came ready to participate in demand response programs out-of-the-box, or "DR-ready."

Such appliances in the market would obviate the need for utilities to install special equipment on customer premises, spurring lower-cost, more widespread deployment of demand response resources. DR-ready appliances also could enable customers to adjust electricity use according to price or other market signals, without compromising their quality of service.

Making "DR-Ready" Ready for Prime Time

One key to this capability is the need to define a single interface for all major appliances or devices. A built-in socket could provide power to a communication device that an appliance owner would plug in after purchase, just as generic Wi-Fi cards work in various personal computers. Work is under way to define such a connection, allowing appliances to communicate via any chosen medium and protocol.

Another prerequisite for DR-ready appliances is a functional specification of what constitutes "DR-ready" for specific types of appliances, enabling manufacturers to develop qualifying products.

Researchers at EPRI's Knoxville laboratories have demonstrated the transformation of existing consumer electronics devices into DR-ready resources by adding software that allows consumers to set controls and manage energy consumption according to prevailing grid or market conditions. This highlights demand



response potential for consumer electronics, which represent a large and fast-growing source of load that already incorporates intelligence and network capability.

Overcoming Consumer Resistance

Research on traditional demand response reveals that up to 80% of customers fail to understand its value proposition, with 60% balking when installation is described. The bottom line: only 6% of the targeted consumers subscribe to utility-sponsored programs. With a simplified, built-in customer interface, DR-ready programs are far more likely to succeed, yet they must address some fundamental challenges. For example, utilities and manufacturers need to collaborate on a simple, standardized system with effective customer communication to support it. Whirlpool Corporation research on time-of-use appliances highlighted the business risk associated with introducing overly complex products that are not "user friendly."

EPRI is addressing these and other barriers to implementing DR-ready systems, such as the lack of an optimal communication protocol and guidelines for product attributes desired by utility and other stakeholders. Ultimately, DR-ready appliances will become available in the market through research, collaboration, and large-scale field trials.

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