# ENABLING DISTRIBUTED GENERATION AND DEMAND RESPONSE WITH ENTERPRISE ENERGY MANAGEMENT SYSTEMS

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## INTRODUCTION

An escalating demand for power has created two challenges for the energy industry: today, the problem is lack of generation; five years from now, it will be bottlenecks in the transmission and distribution infrastructure. Although demand response can solve the short-term problem, only distributed generation can solve both.

Demand response and distributed generation programs are becoming reality thanks to breakthroughs in enterprise energy management (EEM) and alternative generation technologies. These tools can deliver the quantity, quality and cost of power mandated by an expanding digital economy, growing environmental concerns and deregulation.

As greater numbers of power producers enter the picture and energy traders ask for more real-time information, the decentralized monitoring and control of energy and power quality is becoming a critical requirement. Information about every aspect of the power system is being shared at lightning-fast speeds and all players have to react just as quickly.

## THE DRIVE TOWARDS DISTRIBUTED GENERATION

The digital economy, environment and deregulation are defining a new set of power supply requirements—requirements that can only be served through *distributed generation*, a system of small decentralized power plants situated close to end-users. Distributed generators can supply electricity to a single location, or pump power directly into regional or national electricity grids. The plants are owned or leased by utilities, energy service providers, independent power producers or end-users.

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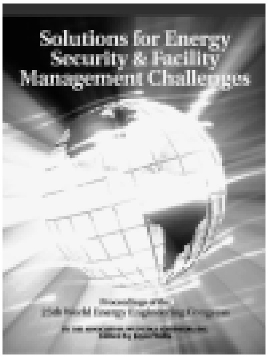
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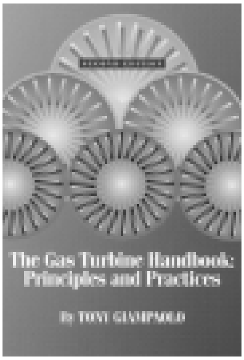

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Distributed generation is becoming more feasible now that small-scale power plants are dropping in price and technologies for data communications and control are increasingly intelligent.

## The Digital Economy

Digital economy enterprises—data centers, call centers, semiconductor fabrication plants, and other computer-controlled mission-critical businesses—are the fastest-growing segment of power consumers.[1] Unfortunately, the current infrastructure cannot meet their escalating needs for quality or quantity of power.

These enterprises require nearly 100% "uptime" to guarantee the integrity of their products or services, but the power grid can deliver only 99.9% uptime or "three nines" of power, the equivalent of eight hours of outages per year. Improving reliability is difficult and expensive because long-distance transmission lines are routinely exposed to damage from animals, trees, lightning and other intrusions. These types of disruptions can be tolerated by lighting systems, industrial motors and air conditioners, the three waves of 20th century invention, but not the data and communication assets of the digital economy and, increasingly, the process control assets of the "old economy" as well.

Now expectations for reliability are around "six nines" (99.9999%) and as high as nine nines; however, even these indicators of "power on/power off" conditions are not sufficient to measure the level of power quality necessary for sensitive process equipment. Microprocessor-based devices are especially sensitive to voltage sags, swells, spikes or outages that can cause lost or corrupted data, equipment damage and process shutdowns. The only way to manage power quality is through an EEM system that can continuously monitor voltage and current waveforms and capture momentary disturbances for later analysis.

Decentralized power plants, which connect to end-users directly or through shorter transmission lines, are inherent sources of "higher nines" power. EEM systems monitor and control the operation of these plants, communicate real-time generation and consumption data, verify power quality, and trace the origins of power quality events.

These distributed generation facilities also provide a remedy for deficiencies in the power supply. Demand for power to support the Internet alone is skyrocketing. The Internet currently consumes 10% of the electricity in the US, and this figure could rise to 50% in 10 years as usage increases. Both old economy and digital economy enterprises rely heavily on the Internet for supply-chain management systems that require access to information "24-seven." *Telecom hotels* and *server farms* host data and communication assets for corporate clients, and their power densities are approaching 100 to 150 W per square foot, roughly double the most energy-intensive industrial facilities.[2]

Along with more reliance on the Internet comes rising energy bills. Large organizations already spend tens of millions of dollars per year on electricity, so a 10% increase in usage is a huge sum. Businesses can minimize costs by using an EEM system to monitor their load profiles and control the operation of small on-site generators during demand peaks (see Figure 1).

### New Approaches under Deregulation

One effect of deregulation is that generation and transmission companies are reluctant to risk expenditures on large capital projects while their load growth is uncertain, competition continues to increase, and grid requirements are in flux. Load curtailment has always been an attractive alternative to the more costly options of purchasing power from neighboring producers or creating extra generation capacity, particularly large-scale generation facilities that take years to build and then sit idle most of the time.

Today, load curtailment programs and power plants with long development time frames are not enough to meet the growing demand for power. In the last ten years, California's electricity needs have risen 30%, but virtually no new power plants have been introduced. Demand in New York state has grown by 2700 MW in the last five years, but generating capacity has not kept up, increasing by only 1060 MW. In fact, New York has not brought a new plant on-line since 1996.[3]

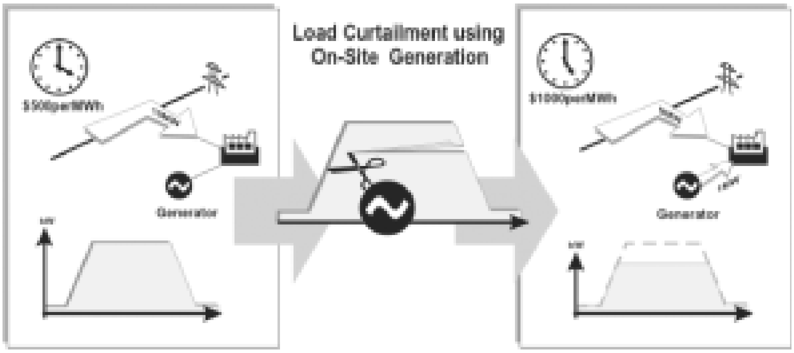


Figure 1. Load Curtailment Using On-Site Generation

Even if additional centralized power plants are constructed, they will operate as isolated islands of generation trapped inside inadequate intra- and inter-state transmission grids. Investment in the transmission and distribution infrastructure has actually declined over the last decade. Between 1988 and 1998, capital improvements to New York's transmission system fell from $307.7 million per year to $90 million per year.[4]

Hence, there is a need for smaller-scale power plants located closer to end-users. In addition to being more affordable, smaller local plants avoid transmission system bottlenecks and suffer lower transmission losses. Usually 68% of the energy used to produce power in a centralized facility is lost by the time it reaches the consumer.[5]

Industrial and commercial energy customers also support the emergence of microgrids (see Figure 2), power networks made up of dozens of linked generation units, each monitoring, switching, and communicating through advanced EEM technology. A microgrid bundles the generating capacity of individual units at each facility and forms a virtual utility that can be run by the consumer coalition or an existing utility.

## Environmental Concerns

Developers of large-scale generation and transmission systems are finding it more expensive to negotiate rights-of-way and government approvals. Community groups have successfully blocked the construction of conventional power plants in their neighborhoods. Federal and state governments have determined allowable emission levels for various pollution sources and placed further restrictions on large generators. Even though some power plants could be retrofitted to meet these new standards, the costs to do so would be astronomical.

The permitting process for small-scale generators is much easier, if even required at all. Stationary pollution sources below a defined size do not need a permit to operate, and microgenerators fit into that category. Their emission levels are also quite low, with fuel cells and

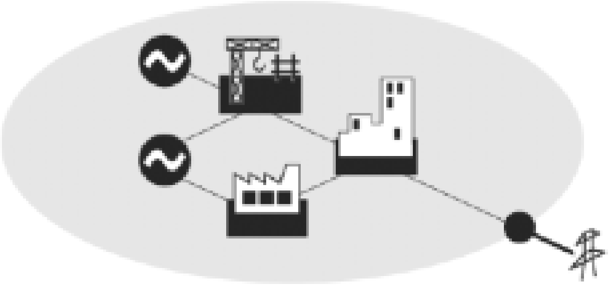


**Figure 2. Microgrid**

solar cells near zero.

While governments offer financial incentives to encourage the deployment of clean generation sources, aggressive environmental regulations are forcing other facilities to close. A large number of highly polluting coal-fired plants will be de-commissioned within the next few years, and the only way to replace that capacity quickly is through distributed generation.

As a result, small, clean, economical generating stations are now more attractive than big, expensive, polluting ones. Microgenerators such as fuel cells, solar cells, and microturbines have always been environmentally friendly, but now their decreasing cost is finally making their widespread deployment possible. Coupled with intelligent monitoring and control systems, these units can reduce the cost and environmental impact of electricity grids.

More advances are on the horizon with many companies cooperating on micropower research projects. In 1999 Daimler-Chrysler and Ford joined a fuel cell partnership with Ballard, Arco, Shell, and Texaco, and later abandoned a coalition that opposed the Kyoto Protocol's limits on greenhouse gases.

## REAL-TIME MANAGEMENT OF THE POWER GRID

Energy is a unique commodity. It cannot be stored, so its generation, delivery and consumption must be managed in real time; otherwise price and availability become unstable.

In the last few years, real-time monitoring, communications and control occurred mainly at the independent system operator (ISO) and regional transmission organization (RTO) level because of the need to control centralized generating facilities.

Now a power grid with decentralized generation must be supported with a spectrum of new energy management tools that help all players, from the ISO to the end-user, stabilize prices and maintain grid stability.

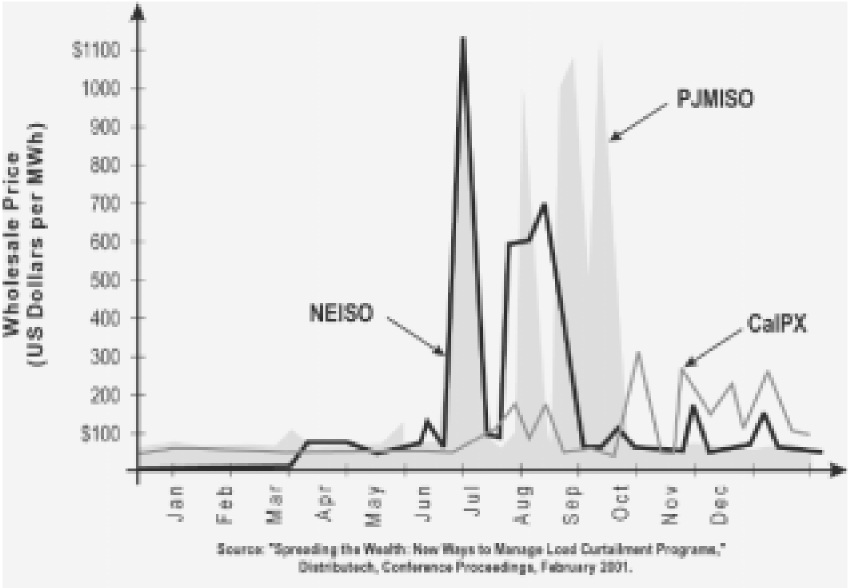
### Stabilizing Demand and Price

The supply/demand imbalance in electricity hinders corporate operations and threatens competitiveness across the globe. New York and the Pacific Northwest have reported the lowest reserves in years, and California has resorted to rotating blackouts in addition to industrial/commercial load curtailment.

Prices on the spot markets have become extremely volatile (see Figure 3) with astronomical hourly spikes.

The main problem has been the inability of the demand side to participate in the market. Competitive markets usually encourage strong interactions between supply and demand forces, but this has not been the case for electricity markets. Until recently, energy consumers could not vary their demand in response to real-time prices, resulting in unnecessary price increases, load growth and threats to reliability. Considering the US energy market is worth $250 billion, a resolution to these inefficiencies would yield extraordinary savings for the entire economy.

Now EEM technology is providing end-users with the right information to make decisions and the real-time tools to act upon them. Instead of waiting for utilities to notify them of load curtailment sessions, end-users can decide to curtail loads based on spot market prices. Their actions, in turn, lower the spot price at peak periods, which benefits every business that needs to purchase that power. End-users are effectively participating in the wholesale electricity market because they can reduce overall demand and moderate price fluctuations.



Source: "Spreading the Wealth: New Ways to Manage Load Curtailment Programs," Distributech, Conference Proceedings, February 2001.

**Figure 3. Wholesale Price Volatility**

(Source: "Spreading the Wealth: New Ways to Manage Load Curtailment Programs," Distributech, Conference Proceedings, February 2001.)

ISOs and RTOs are introducing these capabilities through *demand response* programs where load curtailment credits are based on real-time pricing. Demand response programs are usually targeted at customers that can curtail loads of 100 kW to 5,000 kW or more. If smaller customers want to participate, they can aggregate curtailment with other customers through an energy service provider or load aggregator.

Demand response programs also save money on the supply side. According to Federal Energy Regulatory Commission (FERC) rules, every ISO must set up reserves to keep the grid operating during times of peak demand. These reserves can be in the form of spinning or supplemental reserves (on-line or idle generators), capacity contracts with other suppliers, or demand response or load curtailment programs.

By choosing a demand response program instead of a spinning reserve, a regional operator can save tens of millions of dollars. For example, ISO New England must maintain over 3,500 MW of generators that run at low levels just so they are available to produce additional power on short notice, and this is costing \$30 million.[6] A demand response program reduces that need.

## Stabilizing the Grid

Demand response is the interim answer to the supply/demand imbalance. It's also accelerating the development of a real-time technology infrastructure for the long-term solution: distributed generation. Distributed generation, in the form of standby generators, currently accounts for 10% of generation capacity in the US, and is expected to increase to over 30% of capacity in the next 10 years.[7]

One question concerning distributed generation is the stability of the power supply. Historically, utilities and ISOs have been responsible for grid stability, but as soon as hundreds of independent power producers start pumping power onto the grid, they need to bear part of the burden. That's where affordable, real-time EEM technologies come into play.

For all supply and demand side equipment to function properly, electrical voltages must be maintained within a reasonable range, usually within ±5% of nominal. Voltage control is becoming more complex as the energy industry is restructured and responsibilities are segregated across a number of different generation, transmission, marketing and regulatory entities.

Real-time EEM systems must be able to control voltages by automatically managing *reactive power*, the power wasted by any load that stores energy and transfers some of that energy back to the generator. Inductors and capacitors store energy. Nearly all power system components and end-user facilities—overhead lines, underground cables, transformers, motors, and fluorescent lights—are inductive or capacitive loads. That means some current carried by the transmission system transmits wasted energy (reactive power) and the rest transmits useful energy (real power).

Because transmission lines and transformers can only carry a limited amount of current, the reactive current increases congestion by lowering the capacity of the system to move useful energy. Power providers want to minimize reactive power flows because they reduce the ability of generators to supply real power.

Conveniently, the source of the problem also points to the solution: the currents in capacitors and inductors on the same transmission system move in opposite directions. Because current in a capacitor rises while current in an inductor drops, the two can be used to cancel reactive power flows. End-users often install capacitors to compensate for their inductive loads. Load serving entities (LSEs) install capacitor banks, synchronous condensers and generators at various points in the transmission and distribution system. All these devices can generate or absorb reactive power.

The requirements for reactive components on a transmission system are constantly changing with load levels, generation patterns, and contingencies like generator failures or line faults. A real-time EEM system must control these reactive loads in real time to prevent them from affecting end-users.

Distributed generators also need EEM to respond to these changing conditions and supply some reactive power, or they would create voltage control problems for the grid. But induction generators such as windmills and solar cells only absorb reactive power; they don't supply it. Moreover, because their output fluctuates, their demand for reactive power fluctuates as well. So to control system voltages, they are isolated from the grid with solid-state electronic devices that simulate reactive power output. This scheme also allows a generator's frequency to be controlled independently from the power system frequency so that gas-fired turbines can operate at very high speeds and solar cells can generate direct current.

Frequency is another grid stability issue. Power must be maintained within a narrow window around 60 Hz. Frequency variations occur on a small scale when there is a slight supply/demand imbalance, and on a large scale when a generating unit suddenly fails. To ensure that frequency deviations are contained, distributed generators must react instantly by coming on-line within seconds, or end-users may be surprised with interruptions.

Overall, an EEM system can stabilize the grid all the way down the power delivery chain by controlling voltage and frequency, managing congestion, coordinating protection and fault clearing, and automatically activating reserve capacity. Because operations have to happen in real time, all EEM devices need direct connections to public communication networks such as the Internet, wireless and paging infrastructures.

## DEPLOYING REAL-TIME TECHNOLOGIES AND DISTRIBUTED INTELLIGENCE

The success of demand response and distributed generation depends on the technology behind real-time data gathering and communications. An EEM system has to alert thousands of sites to spot-market prices, confirm remote operations in seconds, and correlate all events with subsecond precision. It must immediately and accurately verify curtailment and generation activities to help operators maintain grid stability, and assign the appropriate credits or penalties.

To carry out all these activities, intelligent monitoring and control devices should be distributed at inter-ties, generators, and customer service entrances. Also, every command-and-tracking workstation from the ISO to the end-user should be equipped with EEM software for systemwide or local situation analysis, load aggregation, remote control and reporting.

This combination of hardware and software can only answer the energy industry's needs if it meets four basic criteria:

- **High Accuracy**: It must meet nationally-recognized revenue-metering accuracy standards because regulatory bodies, LSEs and end-users need an audit trail to prove exact sequences of events and finalize transfers of money.

- **Reliability**: It must be an industrially hardened platform able to continue operating and store data in the event of power disturbances or communication interruptions. It must withstand a variety of conditions defined by ANSI or IEC for revenue meters.

- **Affordability**: It must be cost-effective to deploy and maintain, both in labor and equipment, or else the investment cannot be justified to owners, directors and other stakeholders. It should maximize the intelligence in each device, minimize the number of separate components, and allow easy data access through public Internet, wireless, satellite and paging networks.

- **Instant Communications**: Each device must automatically transmit raw or pre-analyzed data directly to public communication networks, and leverage the existing Internet infrastructure for easy scalability. The device should also issue control signals directly to other equipment, and support simultaneous data transfers to ISOs, LSEs and end-users so that all participants have the same information.

All four criteria call for the use of intelligent power meters with support for load profiling, power quality analysis, control, and multiple communication ports and protocols. A combination of PCs, RTUs, PLCs and external modems at each site may have similar technical capability, but multiple discrete devices are more expensive to set up and maintain. They require more wiring, power supplies, and replacement parts, and more maintenance time to pinpoint the source of glitches should they occur. Some components may also be more susceptible to failure during power quality disturbances.

Intelligent power meters can also work within firewall restrictions that are set up by information systems groups to restrict outside access to corporate networks (see Figure 4). The meters can transmit e-mail messages or serve data directly to web pages, assuring both worldwide data access and corporate security.

To optimize value and reliability on the software side, workstations should be located away from the "front lines," where only the industrially hardened meters need be. Also, people that just want information—not analysis or control capabilities—shouldn't have to install specialized EEM software. They can work with web browsers or e-mail to access data.

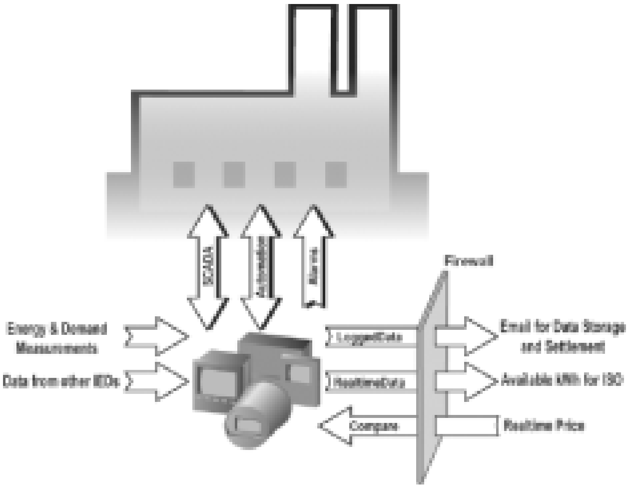


Figure 4. Intelligent Power Meters

Other participants, mostly operators, need workstations with EEM software for enterprise-wide monitoring, dispatch, and reporting, along with a few high-performance servers to manage databases. These operators can exist anywhere in the power delivery chain—at ISOs, LSEs or end-user facilities. Command-and-control software must also support multiple protocols and standards, such as MV-go and ODBC (Open Database Connectivity), so that enterprise-wide data can be collected, analyzed and reported, and control actions determined.

To ensure proper functioning of the grid, every distributed generator should have an intelligent power meter for monitoring, control and communications. The meter must continually transmit current conditions at the generator's interconnect point to the ISO, distribution company or utility so they know when the generator is on-line, and can decide whether or not it should be. The meter should also receive control signals, and when a fault occurs, respond by quickly disconnecting the generator from the grid.

In a demand response program, an energy consumer's EEM system monitors the real-time market price of electricity through XML links to Internet wholesale exchanges. The EEM system correlates the data with building usage, manufacturing schedules or wastewater treatment functions. If the price of electricity climbs beyond the customer's threshold, and curtailment is the right alternative based on marginal costs of production, the EEM system sends a signal to the intelligent power meters to switch off equipment or start up on-site generators until the price drops again. Meters provide continuous real-time data to the ISO to show a drop in demand. The LSE's EEM software tracks the responses of all participants so that actual curtailment is verified and customers are paid appropriately by the power pool for their reduced consumption. EEM software generates reports that correlate billing data with curtailment operations and automatically adjusts customer bills with credits or penalties. The software and meters can automatically update a web page for each customer with real-time loads before, during, and after curtailment, and estimate the credits earned. By tracking overall load reductions, the LSE can calculate real-time cost savings.

In a traditional load curtailment session, a utility's operations center (rather than the end-user) is constantly monitoring the availability and price of power, along with current and predicted demand. Depending on these key factors, as well as the time of day, the system operator may decide that the trend line isn't favorable and the utility cannot meet impending demand. If that happens, the operator activates the software to automatically notify thousands of customers by pager or e-mail, or dial out to the meters located at selected customer sites. A few minutes after first contact, customers must have reduced their loads by the agreed-upon amount, or pay premiums for the extra electricity used. Each meter captures energy readings to determine how much energy was drawn from the utility during the curtailment session. The meter also stores information continuously for billing and power quality monitoring purposes. After the session is over, EEM software uploads curtailment and billing data from the meters into an ODB-compliant database.

## CONCLUSIONS

We are on the verge of a new era in power generation and distribution. Breakthroughs in enterprise energy management technology and distributed generation are changing the way grids operate. Along with power generation, other functions are being decentralized; including data gathering, analysis, control and communications.

The digital economy is one of the drivers behind distributed generation because of the need for a higher quality and quantity of power. In turn, the digital economy is solving its own problem by making communications more affordable and pushing intelligence to the microchip level.

All market players require EEM systems to monitor and control power usage, capacity reserves, costs and payments.

- **End-users** need to understand energy consumption patterns and power quality across their enterprises, and determine whether to participate in curtailment programs or distributed generation microgrids.

- **Energy service providers** want to aggregate loads for demand response programs, buy energy at wholesale levels, or offer distributed generation for premium power quality customers.

- **Application service providers** need to remotely maintain and control the generation assets of utilities, energy service providers and end-users.

- **Power producers and ISOs** have to address the supply/demand imbalance with demand response programs and, in the longer term, distributed generation.

The power grids of tomorrow will be more complex but more energy-efficient than the systems of today. With them will evolve EEM systems and service programs to benefit energy suppliers and consumers alike.

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ABOUT THE AUTHOR

**Rene Jonker** obtained his Bachelor of Electrical Engineering (Communications) degree at the University of Victoria in 1992. He joined Power Measurement in 1992 as a design engineer and played a pioneering role in developing microprocessor-based power monitoring and control devices. In 1997, Rene was promoted to engineering manager of Power Measurement's research and development group. In 2000, Rene was promoted to business development marketing manager. As marketing manager for Power Measurement's business development group, Rene is responsible for developing and implementing the company's strategic initiatives, including product road map and marketing campaigns. Rene may be reached at rene.jonker@pwrm.com.

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