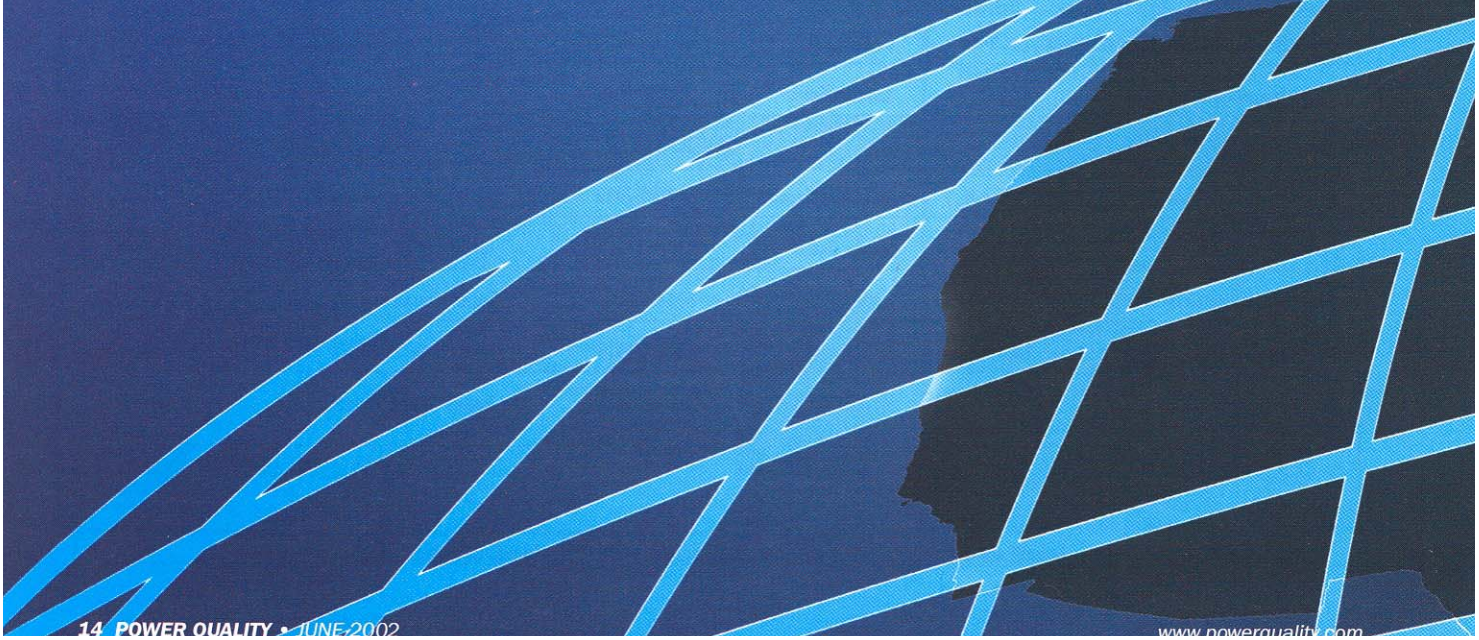
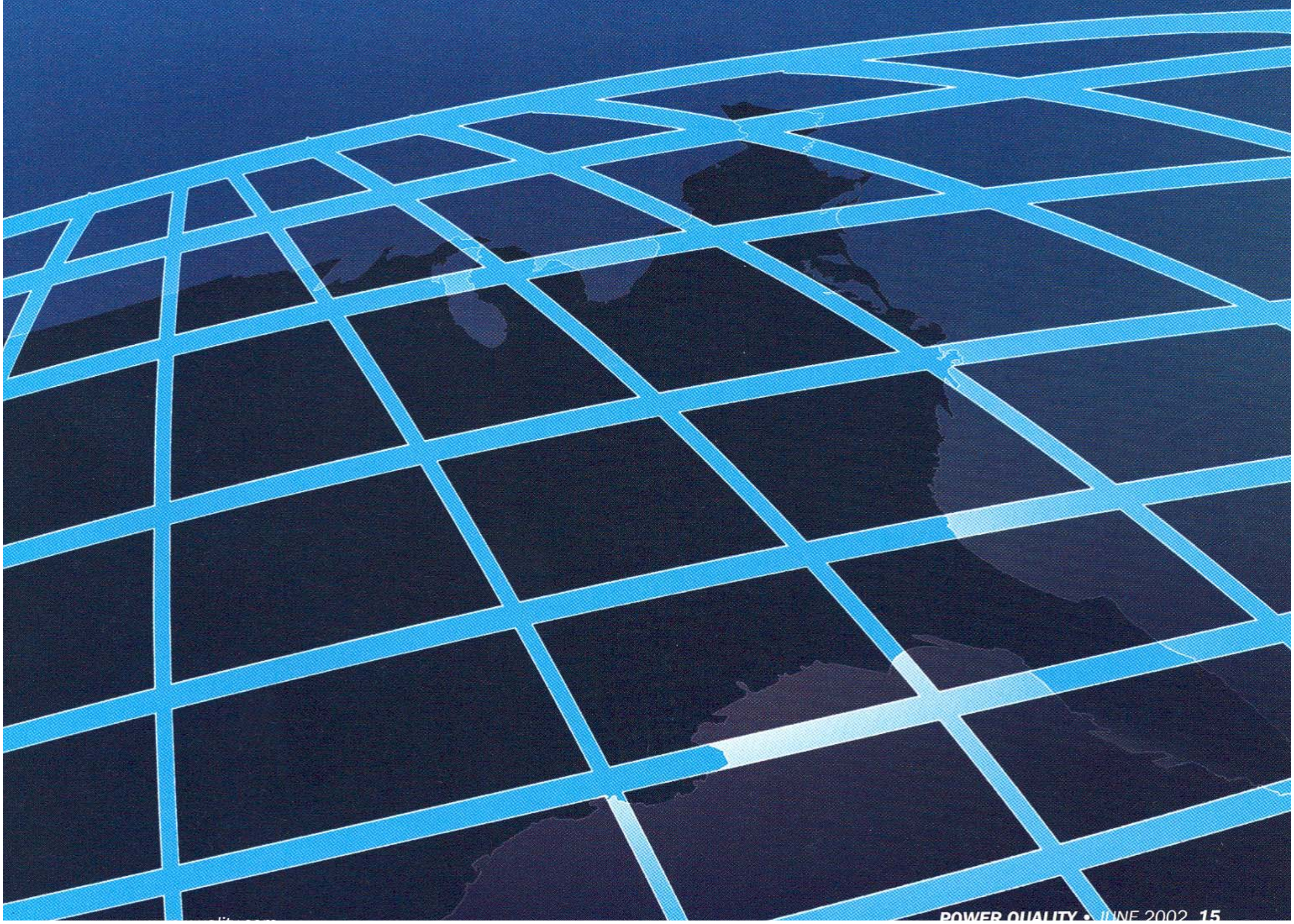
The Future Power Grid

Redefining the Value of Reliability

By Marija Ilic, Massachusetts Institute of Technology (MIT), Cambridge, Mass.



It's time to stop and realize that the current incremental approach to restructuring the electric power industry is simply ineffective. The industry has already undergone several waves of inconsistent changes with regard to power supply, demand, and delivery, but the results have yielded no real benefits for end users. To provide long-term, effective solutions for maintaining an adequate power supply, industry participants must develop a policy that affirms the value of reliability. In fact, the whole notion of reliability must change if the industry ever wants to meet customers' expectations.



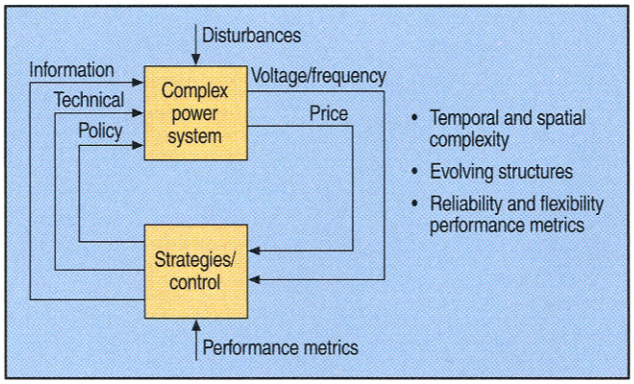


Fig. 1. *Basic interdependencies in the evolving industry.*

The robustness and reliability of the electric power grid reflects a customer's ability to efficiently minimize the effects of low-probability, high-impact disturbances. Achieving the highest levels of reliability is impossible unless the industry fully supports a policy that considers reliability itself as a product with economic value [1].

Assigning economic value to reliability means that customers can benefit from economic incentives, such as paying less if they allow for interruptions. It also forms an infrastructure that allows energy suppliers to develop flexible requirements (or protocols) that adapt to changes in supply and demand and provides opportunities for new capacity investments (see **Fig. 1**).

Fundamental Problems

Current design and operating practices for electrical power systems do not allow these systems to operate both reliably and efficiently. Systems are at risk of blacking out or costing too much—or both. To effectively change the industry's attitude toward reliability, several fundamental problems need to be addressed, including:

Efficiency issues. One problem is that the traditional regulated industry has no strong incentives for efficiency. The tendency is to overdesign electrical systems and then be paid for cost plus guaranteed profit. Despite system overdesign, engineers still can't guarantee reliability because it's difficult to manage the technical difficulties associated with low-probability, high-impact events; these events will happen, but one can never design for all of them.

Efficiency is also difficult to achieve in deregulated industries because the economy is a dynamic process that no one can model, much less control. Furthermore, if one begins to value such intangibles as reliability, the dynamics become even more difficult to model.

Another problem is that the lack of value for reliability produces a tendency to design and operate for efficiency at the expense of technical robustness. For example, no one in this industry is specifically penalized for blackouts. Consequently, the economic pressures to transfer larger blocks of power over longer distances (for profit) stress the system and increase the grid's risk for blackouts.

Achieving the highest levels of reliability is impossible unless the industry fully supports a policy that considers reliability itself as a product with economic value.

Economic factors. The players in today's electricity market view economic processes through a short-term window. However, improving reliability requires the management of longer-term financial and/or physical risks, which requires longer-term incentives. Long-term incentives require time periods great enough to allow for the dynamic economy.

The industry will move forward only when major efforts are made to develop incentives for capacity valuation under market uncertainties and equipment outages. Such efforts would include developing new software tools for the online management of reliability-related uncertainties.

An even harder problem is creating longer-term transmission markets where the following occur:

- End users purchase transmission rights at value to hedge against real-time congestion uncertainties.
- The cost of the rights promotes efficient and reliable investment in the transmission system. (The Federal Energy Regulatory Commission is struggling with this now.) A peculiar issue here is, unless reliability-related risk management is valued as a separate service, it becomes almost impossible to differentiate between hedging against financial risks and the physical risks themselves.

Incentive inequities. Another current problem is the major inequities between incentives given to power producers, marketers, consumers, and delivery companies. Currently, power producers and marketers alone receive incentives. It's critical to introduce technologies and policies that make groups of consumers more responsive to system conditions.

Also, to facilitate the penetration of technologies, the industry must move beyond the guaranteed, cost-plus-fixed-profit payment for transmission. If it doesn't, it will be difficult to support sustainable transmission technology.

Technological incompatibility. The technologies that will shape the future structure of the industry are already here, yet many of them are incompatible with current practices. The existing grid relies mainly on large-scale power plants. It isn't equipped to handle new technologies such as small, distributed generation.

Other new technologies, including long-available, setback thermostats; automatically balanced demand; and adjustable speed-motors (all supported by various metering and switching devices) require much more active participation from electricity users.

Some users may want a choice of more environmentally sustainable power than currently provided by existing plants. Others may prefer lower cost, greater control over power availability, or the potential for lowering payout by selling cheaply generated solar or wind power back to the grid.

Similarly, transmission and distribution will involve vast arrays of controllable switches to implement flexibility, many of these being located closer to the users. More localized storage of energy, particularly of locally generated solar or wind power, also appears likely. Such storage will have the fundamental value of enabling the users to acquire energy at a lower price, for use when it's more expensive. With more effective, lower-cost devices, storage could become routine, and potentially widely distributed.

Software deficiencies. The software-based methods needed to transform the grid into a highly decentralized state are far behind what's necessary and possible.

For example, it's possible for some software to reaggregate and reconfigure the market, depending on the patterns of use or demand and the quality of power required. With these capabilities, a viable new industry might center on brokers who "wheel and deal," owning no assets for generation or transmission themselves, but servicing the software-reconfigured demand. Such brokers are already present in the industry, but they can't operate with poorly defined market rules—particularly in relation to reliability risks.

The most desirable grid would feature hardware and software that rapidly adjusts to real-time data rather than operating on forecasts that might be wrong.

A New Strategy

Dealing with the aforementioned problems will require the industry to forge new policies to meet future power demands. One necessary change, for example, is to abandon rigid reserve requirements and develop protocols that would yield flexible and robust power delivery at the same time [2]. Current reliability criteria (reserve requirements in particular) fail to guarantee the reliability specifications desired by customers.

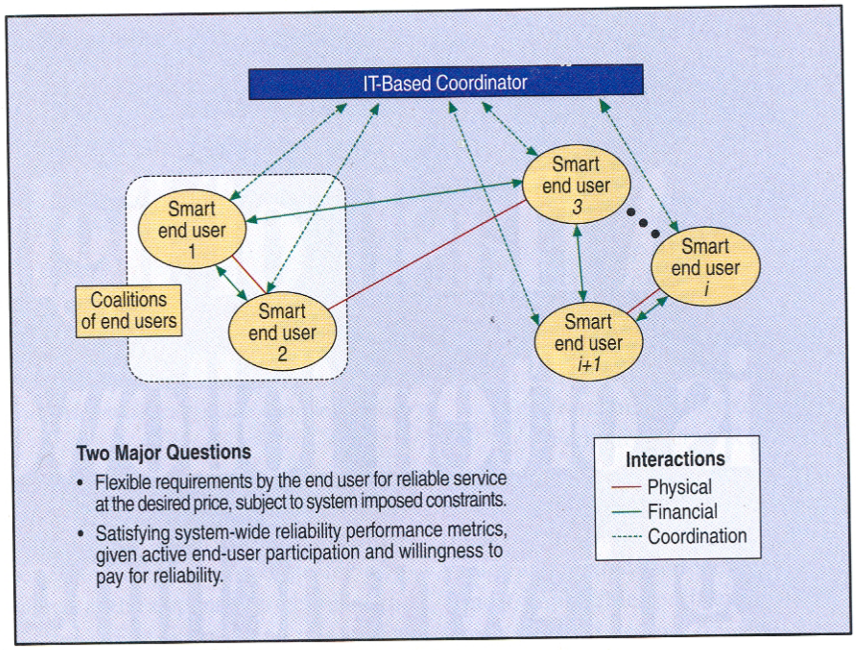


Fig. 2. *Interconnections for distributed reliability*

At the same time, the current reliability criteria are major obstacles to the efficient use of various resources [3, 4]. Part of the solution requires active participation by end users. They must specify their demand for reliability and acknowledge their willingness to pay for it [1, 2, 5, 6].

The most desirable grid would feature hardware and software that rapidly adjusts to real-time data rather than operating on forecasts that might be wrong.

Another good step would involve developing a framework for providing reliable and efficient service—one that establishes the basic interdependencies between capacity (generation and/or transmission), including its pricing and the underlying policy (regulation). The problem of unreliable and inefficient system performance can then be viewed as a multilayered problem with specific economic, procedural, and technical objectives.

Of course, creating the necessary framework for flexibility and robustness in complex power systems would be impossible without advanced hardware and software (IT) options.

IT-based control engineering for complex power systems naturally lends itself to the homeostatic concept proposed by Fred Schweppe [6]. Schweppe asserted that system-wide robustness is achieved when all end users adjust to system conditions (such as frequency and voltage), cumulatively balancing supply and demand in real time (see **Fig. 2**).

Fortunately, major advances in IT and small-scale sensors and actuators make distributed intelligence a reality by helping to develop models that verify and update the data in an online setting. This is a qualitative departure from the static coordination and conservative design for robustness found in older infrastructures.

Schweppe's basic concept, however, needs tremendous extensions. The ideal system would provide coordination through information requirements or protocols. For example, any device attached to the power grid might be required to "announce"

Continued on page 21

Continued from page 18

itself and its characteristics (i.e., how much power it uses, or how much it might generate). In any event, regulations will be needed to assure that the necessary information is provided to coordinate the system, preferably in some automated, nonintrusive way.

The benefits of an IT-based infrastructure cannot be underestimated. With it, many small customers could form larger coalitions for the purpose of negotiating the best possible rates and services. It would also encourage energy providers to build power portfolios with a wide variety of services and options. IT-based protocols play a major role in interconnection by making real-time data available to all parties simultaneously.

Conclusion

Ensuring reliable operations for the changing electric power industry requires a major systematic overhaul. The most effective industry structure is one that explicitly defines and values supply and demand, reliability, and high-quality service.

Creating such a structure, however, presents system operators with a real challenge, especially while there's a need to meet short-term operational reliability under competition. The challenge is not impossible, but it is important. Adequate power supplies in the future depend upon the industry's ability to change its policies and practices today. **PQ**

Marija Ilic is a senior research scientist with the electrical engineering and computer science (EECS) department at MIT in Cambridge, Mass. You can reach her at ilic@mit.edu.

References

1. *Fumagali, E., Black, J., Ilic, M., and Vogelsang, I., "A Reliability Insurance Scheme for the Electricity Distribution Grid," Proceedings of the IEEE PES summer meeting, Vancouver, Calif., July 2001.*

2. *Ilic, M., "Model-Based Protocols for the Changing Electric Power Industry," Proceedings of the Power Systems Computation Conference, Seville, Spain, June 24-28, 2002.*

3. *Arce, J.R., Ilic, M.D., and Garces, F.F., "Managing Short-Term Reliability Related Risks," Proceedings of the IEEE PES summer meeting, Vancouver, Calif., July 2001.*

4. *Yoon, Y., and Ilic, M., "A Possible Notion of Short-Term Value-Based Reliability," Proceedings of the IEEE PES winter meeting, New York City, N.Y., Jan. 27-31, 2002.*

5. *Black, J.W., Watz, J., and Ilic, M., "Potential Benefits of Implementing Load Control," Proceedings of the IEEE PES winter meeting, New York City, N.Y., Jan. 27-31, 2002.*

6. *Schweppe, F., Tabors, R, Outhred, H., Pickel, F., and Coc, A., "Homeostatic Control," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-99, No. 3, pp. 1151-1163, May/June 1980.*

YUASA

Sealed Lead Acid UPS Batteries

No Minimum Order
Get Your Equipment Back On Line Fast Without The Hassle Of Having To Deal With Minimum Order Requirements

Highest Quality Available
Yuasa Brand Sealed Lead Acid UPS Batteries Are Used By More UPS System Manufacturers As Original Equipment

Exact Replacements
With Over 25 Yuasa UPS Battery Sizes To Choose From We Can Provide You With Quality Exact Replacements

Same Day Shipment
Fedco Electronics, Inc. Has The Entire Range Of Yuasa Brand UPS Batteries In Stock And Ready To Ship Today

"Visit Our Web Site For Full Product Listing"
www.fedcoelectronics. com

Call For Free Battery Catalog

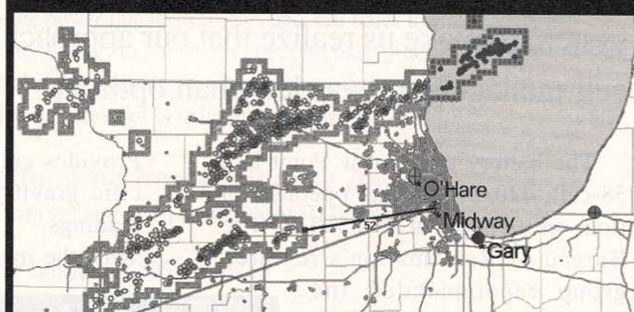
Toll Free: (800) 542-9761

FEDCO™
FEDCO ELECTRONICS, INC.
P.O. Box 1403
Fond du Lac, WI 54935-1403

Fax: (920) 922-6750

Circle 111 on Reader Service Card

Lightning Early Warning for Mission Critical Facilities



Manage lightning risk
- **Track lightning in real time**
- **Prepare for the threat**
- **Isolate your facility**
- **Protect your equipment**

Global Atmospherics
The Lightning People®
1.800.283.4557 | www.LightningStorm.com
7x24@LightningStorm.com

Ask about our reseller program

Circle 112 on Reader Service Card