Restructuring the thin-stretched grid

GRID MANAGEMENT IS BEING HANDED OVER TO NEWLY FORMED INDEPENDENT SYSTEM OPERATORS, BUT CAN THEY BE EFFECTIVE WHEN MATERIAL AND HUMAN RESOURCES ARE SO STRESSED?

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Senior Editor

AS ALMOST EVERYONE BY NOW HAS gathered, the U.S. electricity industry is being reorganized to allow for power to be traded freely. The general idea is for electricity to be sold by independent suppliers into grids managed by authorities independent (more or less) of commercial interests.

So far, about half the states in the country have adopted rules for separating, or unbundling, generation, transmission, and distribution. Usually, generation is made subject to competition, distribution is left a state-regulated monopoly, and transmission is placed under the management of newly established independent system operators and soon-to-come regional transmission organizations, regulated by the Federal Energy Regulatory Commission (FERC), Washington, D.C.

Both types of organizations are being established by and on behalf of utilities to manage transmission systems. Not-for-profit independent systems operators (ISO) started to be set up first, patch-wise, mainly to meet FERC requirements connected with the opening of systems to competition. Last year, in hopes of making the grids interoperate more smoothly on a national scale, FERC required the power industry to organize itself into regional transmission organizations (RTOs). These can be for-profit and can cover a bigger region than an ISO encompasses.

Although the general shape of the system being formed is not seriously controversial, the details of how to arrive at it are hugely contested. (For that reason alone, the differences between RTOs and ISOs are not easy to capture in just a few words.) Accordingly, and because of grid

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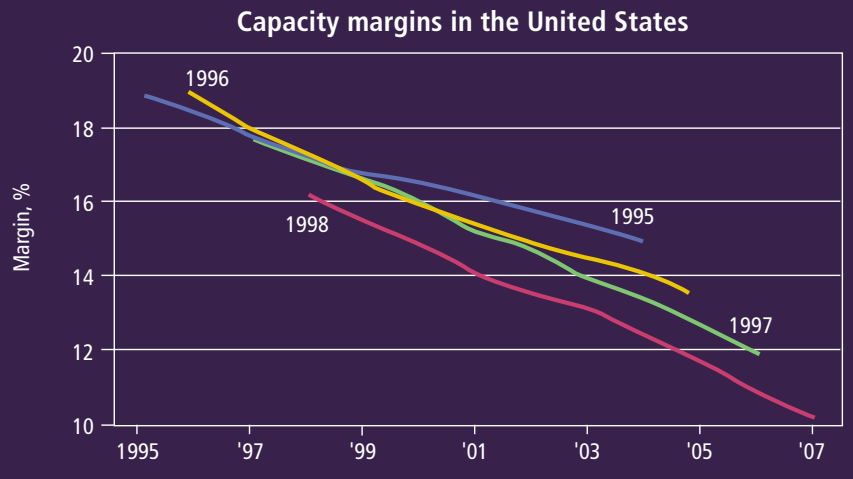

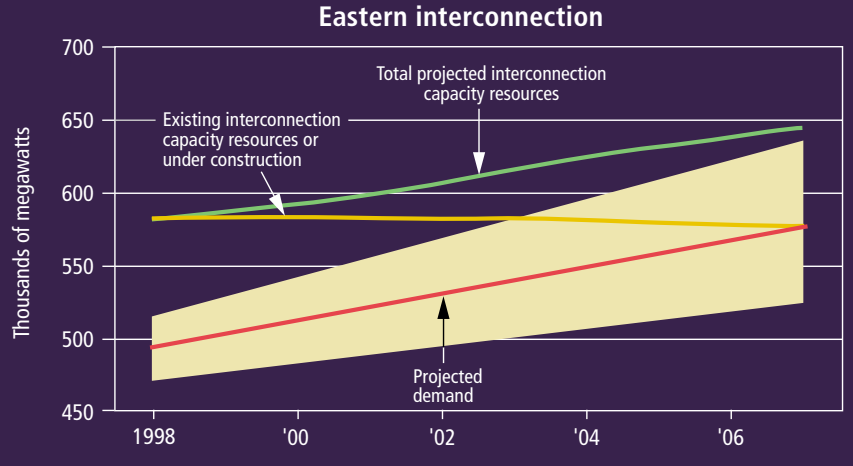

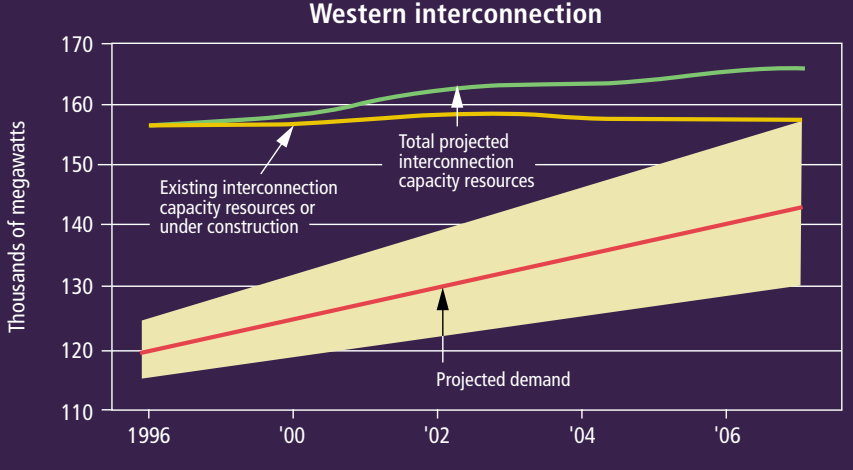

Source: North American Electricity Reliability Council

[1] Capacity margins, or the amount of generating reserves available to utilities and system operators at times of peak load, have been shrinking alarmingly and are expected to shrink still more. A 1998 report by the North American Electric Reliability Council (NERC) reported that summer peak margins could fall below 10 percent in the Eastern Interconnection by 2004 and in the Western Interconnection by 2007.

breakdowns not necessarily related to the restructuring process, the transition to the new regime has stirred mounting nervousness and restlessness.

Even before restructuring began, there were the two major outages in the western grid system in the summer of 1996, the most serious such incident since the infamous Northeast power outage of 1965. Then, during a summer heat wave in 1998, dramatic spikes occurred in wholesale electricity prices, mainly in the Middle West, bankrupting some marketers and brokers. In a similar heat wave last summer, local blackouts and brownouts occurred sporadically in New England, New York, Chicago, and the mid-Atlantic and south-central states.

In the circumstances, the most obviously pressing question is whether the emergent independent grid organizations have adequate authority to guarantee reliable delivery of power. Given anticipated increases in demand, and given that ISOs and RTOs do not necessarily own the assets they manage, will they be able to leverage the necessary generation and transmission resources needed to support the extra loads?

What's more, if new resources must be mustered to meet anticipated demands, will the price of electricity still satisfy expectations that restructuring and competition would mean cheaper energy for consumers? And, as generation is separated from delivery and as power producers no longer are directly under the thumb of local regulators, what about the environment-oriented rules that sought to protect consumers and limit demand growth?

STRAINED INFRASTRUCTURE

Those questions cannot all be fully addressed here, but what gives them special urgency right now is this: the changes to the U.S. power system are being made at a time when its physical and human elements are being stretched to the limit. Whether the talk is of generation and transmission capacity, distribution lines or control equipment, service personnel or simulation engineers, it is the same story: too few resources to easily satisfy demands made on systems designed for radically different requirements. Perhaps most telling is the shrinkage of generating capacity reserve margins, found in virtually every section of the United States [Fig. 1].

Last summer's disturbances brought that situation vividly to light and were the subject of a special investigation by the Department of Energy (DOE), Washington, D.C. Performed by 19 experts and chaired by Paul Carrier of DOE's policy office, the Post Outage Study Team (POST) identified many idiosyncratic local elements, and also drew attention to

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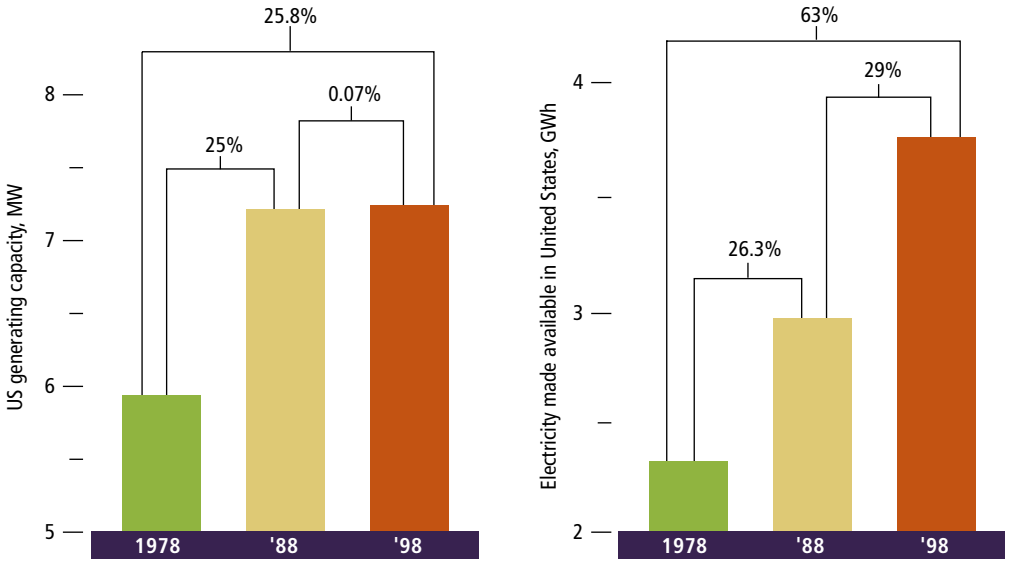


[2] The amount of electricity produced and consumed during the last two decades of the last century increased more than twice as much as generating capacity grew. The results have been shrinking reserve margins and growing burdens on an over-taxed transmission system.

SOURCE: EDISON ELECTRIC INSTITUTE

fundamental commonalities in the outages.

From one point of view, when POST evaluated each of last summer's outages, it found an exceptional situation in every instance. Events in New York City, for example, would never have happened except that the electricity system there is the world's largest and most densely packed, consisting mainly of distinct distribution networks served by underground cables. Those cables take a beating from salted water in the winter and year-round in those neighborhoods where people illegally dump waste like used motor oil down manholes.

In summer, as the Interim Report issued by POST early this year put it, "the increased ground temperature reduces the heat transfer from the underground cables [and] consumers turn on their air conditioners," further raising cable temperature. During the unprecedented so-called heat storm of 6 July 1999, eight of 14 feeder cables to a distribution network in northern Manhattan failed, causing a 19-hour outage.

On nearby Long Island's South Fork, a peninsula stretching eastward into the Atlantic and known for its fast-growing ultrafashionable townships, electricity demand during the July heat wave was 25 percent above the previous year's peak and 18 percent above the forecast peak. Sorely aggravating the situation: interruptions of interconnections to the New York Power Pool and the New England Power Pool, partly because several large failed transformers could not be replaced quickly.

A similar problem with a failed transformer was averted in New Jersey only because spares happened to be ready and waiting, their installation having been delayed by budgetary constraints. In the mid-Atlantic integrated system operated by the PJM Interconnection—a power pool that has reconstituted itself as an ISO and now is looking to become an RTO—the severe declines in voltage were "not predicted for the operating conditions being experienced." Operators had trouble obtaining voltage support in part because, POST found, "there were no economic incentives for generators to produce reactive power." (Transmission voltage is depressed when inductive equipment consumes reactive power, which consists of power in quadrature with real (or active) power. To keep grids running reliably, it must be replenished, preferably close to the point of use, by capacitors or synchronous machines.)

In the Delmarva states—Delaware, Maryland, and Virginia—a main irritant was generators performing below ratings because of heat and humidity. "Planning and operations need to be based on ratings that are relevant at the time of peak loads," commented POST.

COUNTING ON THE MARKET

Probably the gravest shortcomings identified by the outage study team were in Chicago, where the local utility had for years skimped on maintenance. Between 1991 and 1998 maintenance outlays dropped from US $35 million to $20 million, partly because of unexpectedly high costs associated with operating and repairing nuclear power plants, and partly because of a misguided belief that it made more sense in the long run to replace equipment rather than keep fixing it. The DOE team found that the utility also had relied too heavily on past average weather conditions for its forecasts, and so had underestimated the possibility of weather extremes.

A similar situation was found in New England, where the 1999 June demand peaks exceeded every previous peak by a significant margin, stretching reserve margins very thin. The POST Interim Report expects this problem to correct itself in the long run, but leaves some doubt as to the smoothness of the transition: "High electricity prices and several summers of low generation reserves as a result of the early retirement of several nuclear power plants have led generation companies to propose adding more than 30 000 MW of new capacity.…Although much of the new capacity will never be built, many are predicting a generation surplus in New England within a few years. Such predictions clearly indicate that this aspect of the generation market is working…."

POST is apparently postulating that even though not all planned capacity will be built in any given situation, in the end the market will somehow ensure the right amount will be installed. Put another way, it seems to assume that some suppliers will cancel plans because too many other suppliers appear to be getting into the market; yet the appropriate number of suppliers will stick with investment plans.

While that logic involves a leap of faith, it may in fact be borne out. "In the past," commented Vasu Tahiliani, vice president of market development for DMR Consulting Inc., San Jose, Calif., "utilities watched the system peak demands and were delighted to see higher peaks. The utility planners compared the new peaks against installed capacity, and when the reserve margins fell below a threshold the utility went running to the regulators asking for permission to build new power plants.

"The resulting process of regulatory approval and environmental clearances, cou-

pled with long construction times for thermal steam-condensing power plants, took anywhere from 10 to 20 years. One positive impact of new technologies today is that now, in contrast to the past, one can add a 100-MW combustion turbine with just 12 months' lead time."

The Edison Electric Institute, Washington, D.C., has reported that investor-owned utilities have in fact markedly increased investments in generating capacity. In 1998 their expenditures on new construction rose 17 percent, or $3.9 billion, to $27.1 billion. Outlays on transmission and distribution infrastructure increased 12.2 percent to $12.8 billion.

Clear signs that the market is responding are also seen by executives at the North American Electricity Reliability Council (NERC), Princeton, N.J., the self-regulating reliability organization that the utility industry established after the 1965 blackout. But they are keeping their fingers crossed as to whether the response will be adequate or right-sized.

THE BIG PICTURE

Though the Department of Energy's outage study team has provided an admirable account of last summer's power problems, the constraints under which it operated somewhat limit the usefulness of its final report. As an investigation sponsored by the U.S. government, POST was charged with making recommendations relevant to Federal authorities. Yet most of what it studied was local in scope. Moreover, team members were under considerable pressure from interested parties not to step on the toes of local regulators or unduly advance or revive the idea of central planning.

At so-called stakeholder workshops, held in January in San Francisco, New Orleans, La., and Newark, N.J., to discuss the Interim POST Report, a constant refrain from utility representatives and energy consultants was that the team members should avoid drawing conclusions that called the process of introducing competition into question.

Accordingly, the Final POST Report draws carefully circumscribed conclusions and does not put last summer's scattered events into a broad national context. Still, given the omnipresent pattern of excess demand and constrained supply found in the 1999 outages, it is not hard to fill in the background. Indeed, the historical data paint a dramatic picture.

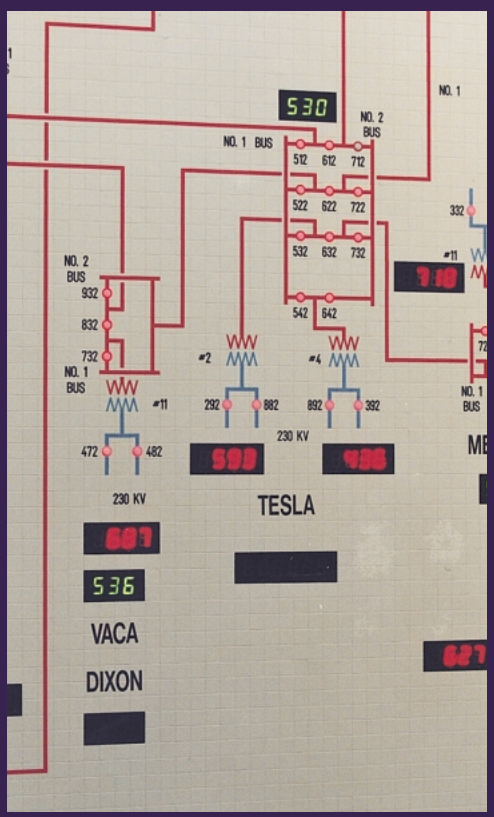
From 1978 to 1998, electricity consumed (or made available) in the United States grew about 63 percent [Fig. 2]. While that represented a modest compounded annual rate of less than 2 percent, that slow growth induced a state of complacency in the nation. Generating capacity grew just 25.8 percent during the same 20 years. During the second decade, indeed, it stayed flat while demand increased 29 percent.

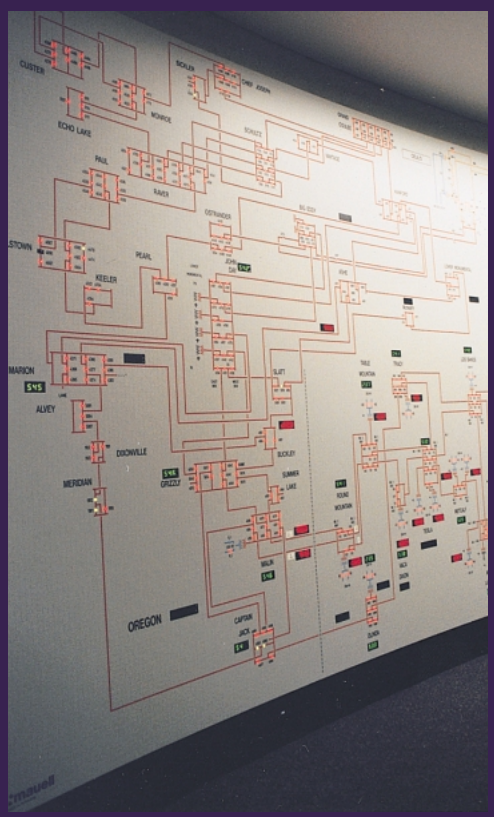
It bears noting that a hefty share of capacity growth from 1978 to 1998 was in nonutility generation, mostly cogeneration of electricity for the grid by industrial producers—a practice greatly facilitated by the Public Utility Regulatory Policies Act of 1978 (Purpa). Nonutility generation mushroomed 550 percent, from 79 gigawatts to 514 GW. Electricity imports also climbed significantly, from 19 to 29 GW.

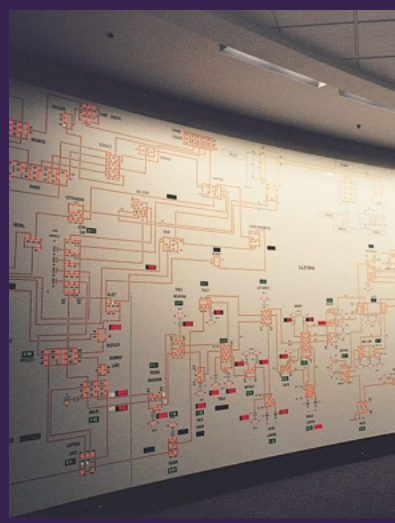
While good data beyond 1998 are not generally available, the overall perception is that demand has turned more sharply upward, thanks to expanded use of computers and information appliances, more intensive use of air conditioning, and more frequent and intense heat waves. Meanwhile, the demand-side management tools that regulators encouraged utilities to use in the '80s and '90s to conserve energy have atrophied, as electricity supply has gone competitive and the regulatory framework has loosened. At the same time, new generating capacity (and transmission) has been slow to materialize, out of uncertainty about compensation for new investments in the new regulatory regime.

The outcome: capacity margins, meaning the amount of generating capacity available during peak demand, are shrinking virtually everywhere in the country. "Capacity margins are eroding to dangerously low levels" and "generating capacity additions [are] not keeping pace," to quote from a reliability assessment report for the years 1998–2007 issued at the end of 1998 by NERC. So inter-regional inter-

PHOTOS 1,2 AND 3 FROM LEFT: JOE JASZEWSKI / LIAISON AGENCY INC.







connections are under greater pressure to supply emergency power when one or another region is short, while "delivering those resources to deficient areas may become more and more difficult as the transmission system [itself] continues to become increasingly constrained."

Transmission capacity has remained flat in the most recent years for which data are available, yet the number of transactions involving bulk transfers of electricity over transmission grids has soared astronomically. Data from the Edison Electric Institute record just 1 150 308 km of overhead line over 22 kV in 1998, versus 1 131 985 km in 1996. NERC reports that planned additions to the bulk transmission system consisting of lines carrying over 230 kV actually decreased during the five years ending in 1998.

Relying on NERC transmission data, the Electric Power Research Institute, in Palo Alto, Calif., sounded an alarm in the electricity roadmap for the next century it issued last fall. "The value of bulk power transactions [transactions for which there is a contract] has increased four-fold in just the last decade," it wrote, "so that about one-half of all domestic generation is now sold over ever-increasing distances on the wholesale market before it is delivered to customers."

In the reliability council's own words, "As the demand on the transmission system continues to rise, the ability to deliver remote resources to load centers will deteriorate. New transmission limitations will appear in different and unexpected locations as the generation patterns shift to accommodate market-driven energy transactions and new independent generators."

In short, "the transmission system is being subjected to flows in magnitudes and directions that have not been studied or for which there is minimal operating experience." One result, warned NERC, is increased use of cumbersome methods for curtailing wholesale transmission transactions, adding to "administrative burdens on system operators at times when the workload is already heavy." Or, as DOE's Carrier puts it, "The industry is becoming more dependent on operational fixes to relieve transmission congestion rather than expanding transmission capacity."

THE BUSY SYSTEM OPERATOR

As the electricity industry has reorganized or been reorganized to meet new national and state requirements, cope with mounting daily demands, and plan for a still more demanding future, several models have emerged. In some regions in earlier decades utilities had formed power pools to manage shared grids, as in New England and New York or the mid-Atlantic states [see "PJM Interconnection," pp. 50–55]. Now those pools are reconfiguring themselves as independent system operators, seeking to meet a 1996 order of the Federal Energy Regulatory Commission (FERC), Order No. 888, requiring utilities to open their power transmission systems to competition. To the extent they take responsibility for transmission planning in accordance with FERC's 1999 Order No. 2000, which calls on the industry to self-organize into regional transmission organizations, these pools may also qualify as RTOs.

The transformation of pools into ISOs or RTOs involves weighty decisions concerning ownership of transmission assets, who has authority to order new assets built, degrees of influence on tariffs and tariff structures, and more. Will ISOs and RTOs have operating authority to deal with the electricity system's burgeoning complexity? Are their relations with emergent neighboring ISOs and RTOs sufficiently defined? Such questions apply, with added force, for some of the so-called independent system administrators, mainly in the Southwest and Southeast, that have taken a minimalist approach to satisfying FERC Order No. 888 requirements. That is, they are happy to coordinate grid operations for reliability but eschew an active role in long-term transmission planning and authorization of transmission investments.

Often ISOs (such as PJM) will manage the market in wholesale transactions, as well as running the grid and being guarantor of its reliability. But in California, where an all-new ISO was set up several years ago in Folsom, near Sacaramento [Figs. 3 and 4], wholesale power transactions are handled by separate power exchanges and brokers, while the ISO merely manages a market in ancillary services (reactive voltage support and so on). Whichever way you do it, you are criticized.

During the California ISO's first year of operation, its market for ancillary services worked poorly, prompting some to complain that it was too distinct from the market in wholesale electricity—a disadvantage, in some experts' eyes, of separating the power-exchange function from the reliability function. Since in many cases the same party provides both wholesale power and reactive support services, it needs adequate incentives to reserve capacity for such services and make them available when needed.

PJM, following the experiences outlined in the POST reports, promptly gave suppliers better incentives to provide ancillary

[3] The control room [below, closer-up shots to left] of the new California Independent System Operator, in Folsom, houses big boards reporting voltage and breaker status, plus consoles permitting staff to call up detailed information. When there is a voltage sag, for example, alarms will sound on terminals, and operators will typically get on the phone to order corrective measures. Folsom, near Sacramento, is in the state's most earthquake-resistant region and has excellent communications because of an Intel plant sited there.

CALIFORNIA ISO

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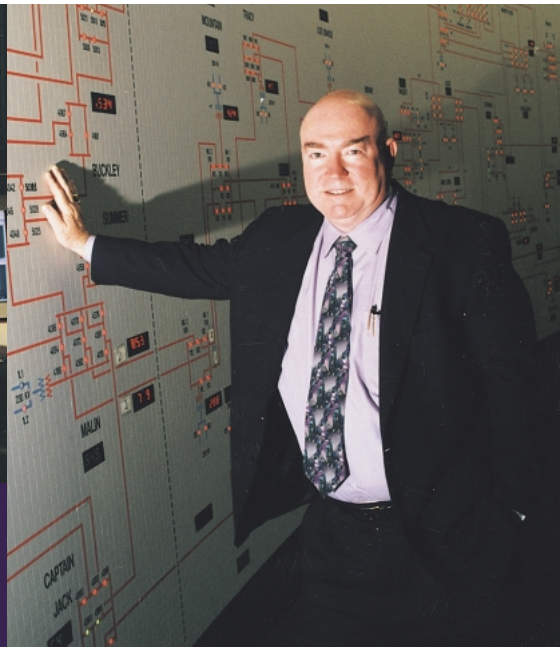

[4] A coordinator [above] in the control room of the California Independent System Operator monitors status of generators, lines, and loads. Before the establishment of the ISO, there was no one central control room providing a complete overview of the state's grid. The control room's head, Ed Riley [right], believes the new setup will go far to prevent the kinds of outages that occurred in 1996 in the Western Interconnection.

services. But its managers report that power coordinators recruited from the gas industry do not always understand the physics of power delivery as well as they need to, and, according to William K. Newman, senior vice president for transmission planning and operations of The Southern Company Services in Birmingham, Ala., "power marketers say they dislike [some aspects of] PJM's system of pricing."

Newman has noted that upgrading energy management systems and security tools to cope with bulk transactions and loop flows (unexpected parallel flows) is a massive undertaking that will cost "billions of dollars. Where will the money come from?" California's new ISO and power exchange cost over $400 million to set up and need hundreds of millions of dollars more annually to operate, he told *IEEE Spectrum*. Utilities in the Midwest also are spending impressive amounts to establish an ISO in Indianapolis, with a big new building and a staff of more than 100 specialists. Those figures tell him right off, Newman said, that these are models they do not want to emulate in the Southeast.

However big or elaborate an ISO or RTO is, there will always remain the questions of whether it is big enough, and how its relations with neighboring operating authorities should be organized. The California ISO, though it probably meets all FERC Order No. 2000 requirements to be considered an RTO as well, has taken the position that the whole Western Interconnection should be a single RTO. (The North American power system consists of four huge semi-distinct interconnections linked and buffered by dc tie lines: the Eastern and Western, flanked in the Southwest and Northeast by Texas and Quebec.)

The Southern Company's Newman personally likes the way the Alliance RTO is being set up in the Appalachian region, involving transmission companies in Michigan, Indiana, Kentucky, North Carolina, Ohio, Virginia, West Virginia, and Pennsylvania. Here, he said, the desired end-state is a Transco that couples ownership and operation of the transmission system but at enough of an arm's length to prevent market manipulation by big players.

Yet, as division chief Kim Wissman, of the Public Utility Commission of Ohio observed at the San Francisco POST workshop, horrendous boundary issues confront Ohio, a partial member of the Alliance system. For one thing, the state is bifurcated by a Midwestern ISO and a Northeastern RTO, with one utility belonging to neither, just to further complicate matters. For another, it is divided by low-cost (coal-burning) and high-cost (nuclear) utilities, with the latter determined to sell its nuclear electricity to the higher-priced Northeast, regardless of local conditions.

In light of such difficulties, Newman's overall conclusion, which few would contest, is that no ISO or RTO "has solved the most significant problems in a fashion that would lead one to believe that the same solutions would be successful if applied across the North American continent."

SCARCE HUMAN RESOURCES

Another thing just about everybody agrees on, above all, the folk in the trenches, is that whenever a utility is pressed for money and time, the first thing to suffer is maintenance of the distribution infrastructure. And in recent years, all utilities have been pressed for money and time.

This was the subject of frequent and vociferous complaint in the POST stakeholder workshops held last winter. At San Francisco, Jack McNally, business manager of Local 1245 of the International Brotherhood of Electrical Workers (IBEW), said the shrinkage in the utility workforce had been enormous, 27 percent nationwide between 1990 and 1998, 17 percent in California. He observed that people might say with some justification that utilities have been cutting fat, outsourcing work, and stopped doing some work. "But the bottom line is clear: there are fewer employees out there… to perform maintenance, and fewer employees to respond to emergencies."

At Newark, Brian McCarthy of the Utility Workers Union of America quoted a 1999 union survey of its 12 largest locals, which found staffing was down nationwide by 20–30 percent. "To put it simply," he said, "there are not enough workers to do the work needed to maintain a reliable electrical system." Critics of such figures point to the migration of workers to the new independent power producers from utilities unbundling their assets, making it hard to assess net aggregates. But union representatives respond, with like logic and reason, that utility linesmen also are being raided by the booming telecommunications sector, which cannot lay fiber optic cable fast enough. An IBEW representative reported at the Newark POST workshop that employees are required to put in more and more overtime, as much as 1000 hours per worker per year, and that the workforce is aging, with lots of attrition. There is a crying need, the IBEW argues, for Federal standards for distribution reliability, maintenance, and safety.

If that is how things look to the linesmen staffing the last lines of defense, how do they look on the first line, where simulation engineers try to anticipate problems long before system elements combine into the

patterns that are the makings of disaster? Not much better if one is to credit John F. Hauer of the Pacific Northwest National Laboratory, a leading expert on the western grid system who served on the POST panel and wrote a recent white paper on reliability issues and system events for the DOE's Office of Power Technologies.

Reviewing lessons of the 1996 western grid breakdowns, Hauer last December wrote of "a tendency to underestimate the complexity of behavior that a large power system can exhibit.... There are numerous accounts of perplexed operators struggling in vain to rescue a system that was slowly working its way toward catastrophic failure."

To illustrate, large-scale voltage oscillations can be an enigma, to both planners and operators. "It is very unlikely that any pre-existing model will replicate such oscillations, and it is quite possible that operating records will not even identify the conditions or the equipment that produced them," said Hauer. "Situations of this kind can readily escalate from operational problems into serious research projects[!]"

Further, said Hauer, planning models used by NERC's Western System Coordinating Council (WSCC) "have been chronically unrealistic in their representation of oscillatory dynamics, and have progressively biased the engineering judgment that underlies the planning process and the allocation of operational resources."

In light of such macrosystem concerns, participants in the POST San Francisco workshop welcomed an announcement by Karl Stahlkopf of the Electric Power Research Institute. He said that the institute was launching a first-ever evaluation of the whole U.S. power system, employing the techniques of probability risk assessment refined in studies of nuclear power plant safety.

Stahlkopf, vice president for energy delivery and utilization at EPRI, said the study, to be based on the NERC reliability regions and their interfaces, would be complete in summer 2001. The Ohio Public Utility Commission's Wissman noted this exercise will be especially constructive if it helps operators and regulators see what regional markets really look like, so that boundary issues can be better resolved.

NATIONAL POLICY ISSUES

NERC has asked for legislative authority to make compliance with its rule-making mandatory, rather than voluntary. The Clinton administration has strongly supported such enabling legislation in principle, but arguably not yet with the vigor required to get it through a chronically recalcitrant Congress.

That said, Secretary of Energy Bill Richardson would seem to be doing his part. When not otherwise occupied with rising oil prices, compensation claims by nuclear workers, and alleged security lapses at the national laboratories, he has given strongly worded speeches calling for enactment of the comprehensive restructuring legislation giving NERC enforcement powers. He has repeatedly said that more summer blackouts will otherwise be the result. But something more like an all-out attack on the part of the Administration may well be required to get the law passed. That is to say, the individuals at the very top may need to get engaged.

The same absence of energy in U.S. energy policy could be said to characterize the Administration's approach to deficiencies in technical and human resources. Although the POST Report and associated documents are full of references to the dearth of satisfactory cable and transformers, insufficient qualified personnel at all levels, ubiquitous shortages of generation and transmission capacity, and drastically shrinking reserve margins, the reader searches in vain for any legislative proposals directly addressing these crying needs. The POST panel recommended that Federal funding for research on reliability be increased to the level proposed in the Administration's fiscal year 2001 budget—$11 million—from the current paltry $3 million per year.

Calls for any kind of direct Federal attack on systemic deficiencies inevitably raised the specter of central planning or even socialism, and trigger anxieties about wasteful government spending. "No engineer would design a system to meet all conceivable requirements, no matter what the cost," the Southern Company's Newman told *Spectrum*. "So are price spikes proof that systems are deficient? Not necessarily!"

Yet it bears noting that some aspects of restructuring have left regulatory voids where previously matters were closely controlled. For example, state boards routinely required utilities to maintain reactive power reserves, but even though the boards now have lost authority over power producers, FERC and NERC have not stepped in with national standards.

Perhaps, even if the Federal government is to stay largely out of the infrastructure business, and if incremental improvements in NERC's operating authority do not excite legislative action, a more eye-catching legislative proposal is needed. How about going beyond what NERC is proposing, and creating a federation of regional or supra-regional reliability boards, with powers analogous to those of the U.S. Federal Reserve banking system, or boards supervised by a Federal enforcement agency like the Securities and Exchange Commission? Such boards could set and enforce generation and transmission reserve requirements, offer ancillary services (rather like the Fed's overnight funds), and set some basic operational standards.

A somewhat different proposal was made at the San Francisco POST stakeholder workshop by Vann Prater, director for transmission development at Dynegy Inc., Houston. Prater called for establishment of an inter-regional "transmission coordinator"—akin to the air traffic control function—to oversee ISOs and RTOs on a supra-regional basis. His view is that seams and loop flow issues are not being resolved fast enough during the FERC-regulated transition to competition, and that some kind of supra-regional authority is needed at least temporarily.

Right now such ideas are unlikely to go anywhere. But just one more very hot summer could soon put them on the political agenda. ◆

TO PROBE FURTHER

Richard F. Hirsh provides an up-to-date and detailed history of the developments that led to the current U.S. regulatory system for electricity in *Power Loss: The Origins of Deregulation and Restructuring in the American Utility System* (Massachusetts Institute of Technology Press, Cambridge, 1999).

The final report of the Department of Energy's Power Outage Study Team (March 2000) is available on the department's Web site at http://www.doe.gov. Also well worth consulting: John F. Hauer and J. E. Dagle, "Review of Recent Reliability Issues and System Events," Pacific Northwest National Laboratory technical report PNNL-13150, prepared for the department's Reliability Program by the Consortium for Electric Reliability Solutions (Certs), December 1999. It can be accessed at http://certs.lbl.gov.

The most recent reliability forecasts from the North American Electricity Reliability Council are available at www.nerc.com/publications/annual.html.

For the operating record of California's restructured system, see D. Sparks, "The California Electricity Market, " in *IEEE Power Engineering Review*, June 1999, pp. 11–12; "California ISO Formation and Implementation," by Farrokh Aolbuyeh and Ziad Alaywan, in *IEEE Computer Applications in Power*, October 1999, pp. 30–34; and Laura Brien's "Why the Ancillary Services Markets in California Don't Work and What to Do About It," in Elsevier Science Inc.'s *Electricity Journal*, June 1999, pp. 38–49.

The best place generally to follow debates about the formation of independent system operators (ISOs) and regional transmission organizations (RTOs) is in *The Electricity Journal*. See also Jim Burke, "Using Outage Data to Improve Reliability," *Computer Applications in Power*, April 2000, pp. 57–60, and Hyde M. Merrill's "RTO Debate" in *Power Engineering Review*, February 2000, pp. 7–10.