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## **Can the U.S. have reliable electricity?**

**Nuclear power plant operators have greatly increased reliability over the past two decades. What can the electric power industry as a whole learn from their experience?**

The United States ranks toward the bottom among developed nations in terms of the reliability of our electricity service. The August 14, 2003 blackout put fifty million people in the dark. A transmission system failure interrupted power to seven million west coast customers in 1996. A worker mistakenly cut the wrong line near Los Angeles in 2005, blacking out two million for hours.

Congress attempted to make power dependable through the Energy Policy Act of 2005 by mandating an Electricity Reliability Organization (ERO). The only applicant for the job is the North American Electric Reliability Council (NERC). While we admire NERC's personnel and view them as a positive force, there are structural problems that will impede their effectiveness in this new role. There is much to be learned from the experience of the Institute of Nuclear Plant Operators (INPO), a voluntary organization with a quite different level of commitment from its members and an exemplary record of reliability and safety.

First we discuss the reliability record for U.S. electricity systems and then review the history of what has been done to improve reliability, including the creation of NERC. We then describe the history of INPO and what it has accomplished. We summarize some of the comments made by the industry to FERC's proposal to create an ERO. Then we address explicitly some of the limitations that will arise in converting NERC into the mandatory reliability organization. Finally, we present some recommendations for how FERC should fulfill its new responsibility for reliability.

Customers in the U.S. lose power for an average of 214 minutes per year. That compares to 70 in the U.K., 53 in France, 29 in The Netherlands, 6 in Japan, and 2 minutes per year in Singapore. These outage durations tell only part of the story. In Japan, the average customer loses power once every 20 years. In the U.S., it is once every 9 months, excluding hurricanes and other strong storms.

Despite decades of sober technical reports written by investigation teams in the aftermath of blackouts, the frequency of electric power outages in the United States is no less today than it was a quarter-century ago. Whether measured in terms of city-sized blackouts or smaller events, the statistics show that reliability has not improved. Indeed, if the data show any trend in the past few years, it is toward lower reliability.

The United States has 80% of its population living in urban areas, compared to 66% in Japan and 74% for Europe, so it is unlikely that urban/rural differences account for much of the reliability dissimilarities. The causes of outages in the United States show there is considerable room for improvement. Excluding major storms, half of the number of minutes of lost power are due to equipment failure (including the 1965 Northeast blackout). One out of every six lost minutes are related to untrimmed trees near power lines. Five percent is due to mistakes by power company personnel (such as the 1977 New York blackout and the 2005 Los Angeles outage).

This history of blackouts creates ample public demands to increase reliability, opening a window of opportunity for the industry.

## What has been done

In 1962, as the scattered power systems in the eastern U.S. were about to be interconnected, ten voluntary regional reliability councils were established to coordinate the planning and operation of generation and transmission facilities owned by their members. Following the 1965 blackout, the U.S. Federal Power Commission recommended that a national reliability coordinating council be formed, and in 1968 the North American Electric Reliability Council (NERC) was formed to coordinate the regional councils. One of NERC's primary functions has been to develop voluntary reliability standards for the regional generation and transmission of power.

In January 1997, recognizing that the familiar landscape of rate-of-return regulation was about to be replaced by a competitive market for electricity, a NERC panel proposed federal legislation that would establish an electric reliability organization with power to establish and enforce mandatory standards. The U.S. Department of Energy endorsed that recommendation in 1998.

Seven years later, the Energy Policy Act of 2005 followed that recommendation, creating a new section of the Federal Power Act that gives FERC responsibility for reliability and authority to certify an ERO. On March 30, 2006, FERC issued its final rule establishing the criteria an entity must satisfy to qualify to be the ERO, including the ability to develop and enforce reliability standards. The Commission intends to certify one such ERO, which may (upon FERC approval) delegate its enforcement responsibilities to regional entities.

If all this sounds a bit like NERC and the regional reliability councils (of which there are now eight), that is not a coincidence. Four days after the final rule was published, NERC filed an application seeking Commission certification as the ERO. NERC hopes to be certified in time to implement mandatory reliability standards early in 2007.

## NERC's ERO proposal

NERC is the only organization proposing to become the ERO. It has requested that FERC approve the existing NERC voluntary standards as the first mandatory reliability standards adopted under the new legislation.

The current program is administered through the eight regional councils. As an example, the regional council responsible for reliability in Florida directs confidential annual self-audits, performs or directs periodic confidential triennial and spot audits, random checks, and

investigations (the latter in response to a complaint or notice of a suspected violation). Monthly reports must be made on such items as transmission protection system misoperations. The entire ERO compliance audit program itself will be evaluated every three years by an outside group.

NERC proposes to continue its program of triennial reliability readiness audits (begun after the 2003 blackout). NERC wants these to “ensure that operators of the bulk electric system have the facilities, tools, processes, and procedures in place to operate reliably under future conditions.” The readiness reports, stripped of business-sensitive data, are to be made public. NERC also plans to compile and publish examples of excellent reliability practices noted during these audits.

The proposal states, “NERC’s budgeting and business plan development processes will be open and will extensively consider industry views. NERC’s independence in this area will be maintained by virtue of the board being the ultimate body to vote on and approve NERC’s and the regional entities’ budgets and business plans, prior to submission to the Commission for approval.”

This sounds promising, but the fact remains that independence is precarious for a body funded by the industry it is supposed to regulate, even with the caveat that FERC must approve the ERO’s submitted budget. The degree to which the ERO will be able to act to increase reliability depends on the seriousness with which reliability is taken by FERC and the ERO’s members, and the balance they strike between profit and reliability expenditures in an often cutthroat competitive environment.

## Reliability in the nuclear industry

On March 28, 1979 Reactor 2 at the Three Mile Island nuclear power plant suffered the meltdown of approximately half its core. “TMI shook the industry to its foundation, ending an age of innocence” according to the chairman of the board of the Institute of Nuclear Plant Operators (INPO), which was formed within the year.

INPO’s mission is “to promote the highest levels of safety and reliability – to promote excellence – in the operation of nuclear electric generating plants.”

The nuclear electric power industry has achieved major improvements in its reliability. At the time of the TMI accident, U.S. nuclear plants were on-line 58% of the time. By 2004, they were producing electricity 91% of the time.

INPO is a big part of the reason for the reliability improvement. When the nuclear industry was rocked by TMI and seven years later by Chernobyl, U.S. nuclear industry executives feared that their plants would be closed. They agreed on a major effort to avoid another mishap. They were given a not-too-gentle push when the Nuclear Regulatory Commission shut down reactors operated by the Tennessee Valley Authority, Philadelphia Electric and other companies until operations and equipment were improved.

INPO’s board of directors is made of up 12 CEOs and presidents of power companies. As the institute states, “The industry’s recognition that all nuclear utilities are affected by the action of

any one utility motivated its commitment to and support for INPO.” The commitment has also made the plants much more reliable – and profitable.

The Institute’s regular evaluations of nuclear electric generators are centered around comparing plant performance to metrics that emphasize safety and reliability. These metrics include the on-line time percentage, unplanned automatic interruptions, safety system performance, chemistry and fuel defects, industrial safety, and plant emissions. The metrics are developed jointly with the World Association of Nuclear Operators (WANO), and goals are set for each type of plant.

Not only does the use of metrics provide targets that can be incorporated into a plant manager’s compensation, they also allow the identification of early signs of performance decline in time to avoid service interruptions or mishaps. In exit meetings at the conclusion of plant audits, the sustainability of plant performance on the metrics is addressed explicitly. Members are provided with comparisons of their plants’ performance with metrics for the industry as a whole. The insurance industry has linked premiums to scores on INPO performance metrics.

INPO makes a distinction between regulations promulgated by bodies such as the Nuclear Regulatory Commission (NRC) and performance objectives measured by metrics. The institute has found that reliability excellence can be achieved by a combination of the two. Industry-wide performance objectives are difficult to meet every year, but provide goals and measurable outcomes; the NRC regulations provide a minimum floor for operations.

Despite competitive pressures in the industry, easy access to plant and equipment performance and operating experience is available on INPO’s secure website for members. As one of the conditions for institute membership, organizations agree to “share information, practices and experiences to assist each other in maintaining high levels of operational safety and reliability.” They agree to assist each other in benchmarking best industry practices.

INPO has recognized that the electric power generating industry may not have all the answers to safe and reliable operations. One of their stated principles is to “use expertise and experience from outside the U.S. nuclear industry.” INPO has formed an advisory council with experts on aviation, insurance, finance, human performance, and organizational effectiveness from the commercial world and universities. They review institute activities and advise the board on objectives, and on methods to meet the objectives.

INPO involves equipment manufacturers and plant designers, who make up a supplier participant advisory committee. Through WANO, INPO brings experience from many countries to bear when performing its plant audits.

To ensure that recent industry experience is embedded within the institute, plant operators loan personnel to INPO, and use INPO personnel on reverse loans.

INPO does not rely on its audit program alone. Special assistance is given to any member who requests it, or whose metrics are trending in a poor direction. These between-evaluation programs proactively help reverse trends, and are prioritized to devote more resources to plants whose metrics show help is needed. The team includes peers from other utilities who have handled similar problems well.

We see the key to INPO's success as the agreement among all nuclear plant operators that one poorly-performing plant presents a threat to the continuing operation of all nuclear operators. As the U.S. system becomes more interdependent, electric power producers using all fuels, not just uranium, are no longer masters of their own destiny. A shortage of generation in Akron can plunge New York into darkness.

The best large coal plants (1000 MW and above) operate 92% of the time (the same as the average nuclear plant), while the least reliable large coal plants operate less than 30% of the time. The average coal plant operates 60% of the time. Surely there is room for improvement. While the future performance of the system is often dependent on the weakest link, failure of a fossil fuel plant has nothing like the impact on public opinion that would result from a nuclear accident, so it is more difficult to command high levels of attention and concern from others across the industry. However, generator unavailability still can dramatically affect the grid. In the rolling blackouts that hit Texas in April 2006, roughly 20% of the generators in the state were unavailable due to maintenance.

### What electricity companies think

In its notice of proposed rulemaking for the ERO, FERC sought comment on which aspects of the INPO's programs would serve as useful models for the ERO and what lessons can be drawn from INPO's complementary role with the NRC.

A third of the responders felt strongly that FERC had no business even discussing the idea. One went so far as to state that FERC was exceeding the scope of its authority by suggesting the establishment of an organization that deals with safety (the respondent ignored the 2005 Congressional mandate for reliability).

A majority of those who commented had positive things to say about the INPO model. One group of large users of electricity pointedly advised FERC, "The Commission needs to overcome the tendency of economic regulation to tolerate mediocre behavior."

A common theme among supporters of the INPO model is that enforcement of compliance with reliability standards should be separated from the collaborative functions that an INPO-like organization would undertake. Several felt that such a separation would be feasible within the ERO: audits for compliance have a very different purpose than audits for excellence.

The periodic site visit assessment of performance was thought to be a key to the success of such an organization, along with the sharing of equipment failure and operational error and event data. However, most felt that performance ratings and reports should be kept confidential. Several organizations noted that the imposition of sanctions by the ERO would have a chilling effect on information sharing within the ERO. The rotation of personnel and senior management involvement were both felt to be important in a best practices organization.

To summarize, the industry responses to FERC's question about possible lessons for the future ERO from the INPO experience included some who felt that the status quo in reliability is fine, some who feel that the regional reliability councils should (in some undefined manner) act as best-practices organizations, and some who felt that national best-practices groups for various

segments of the electric power industry are necessary, but that compliance with minimum reliability standards and achievement of excellence in reliability are two very different functions that must be kept separate.

## NERC as the ERO

NERC and the regional reliability councils began life 40 years ago in an environment of public outrage after the 1965 blackout. Outrage returned 12 years later (the root cause of the 1977 blackout was a utility practice that left a single critical operator without the tools and training to stop a fairly normal occurrence from snowballing). After the outcry following the 2003 blackout, NERC adopted some of the techniques pioneered by INPO, taking steps in the direction of becoming a best practices organization. For example, it has performed “readiness audits” (that are planned to be triennial) of generation plants, transmission operators, and independent systems operators. These audits have led to publicly-posted examples of excellent practice, such as “The Salt River Project provides highly redundant and independent systems and power supplies at its control center that result in an extremely reliable and secure set of tools for its operators.”

However, in proposing to become the ERO, NERC is morphing into a standards setting and compliance organization in collaboration with the regional councils, a role that is filled in other industries by various arms of the government. ERO standards are likely to be set by industry consensus, since a two-thirds vote of NERC members is required for adoption. The standards will vary by region both in response to regional technical differences and to the different character of companies operating in the regions (who will fund the ERO and the regional councils).

There are admirable facets to NERC’s proposal. The record of the past quarter-century has shown that NERC and the regional councils have helped to slow the slide in reliability. By making NERC’s reliability standards mandatory, the ERO should be more effective. However, we worry that, since the NERC standards were regional industry consensus standards, their stringency has been limited by the influence of members with substandard performance, and that such influence could continue in the future. If a consensus industry group, rather than EPA, were responsible for developing air quality standards, SO<sub>x</sub>, NO<sub>x</sub> and particulate levels would likely be much higher in the U.S. today.

The Three Mile Island and Chernobyl incidents convinced nuclear plant owners that they were in immediate danger of having their plants closed and losing billions of dollars unless they could convince a skeptical public and Congress that they could operate safely. The INPO experience showed them that tough standards and cooperative efforts could make their assets more profitable and valuable.

The owners of coal and natural gas fired generators and of transmission and distribution lines have no reason to fear that a mishap would shut their plants. They might be tempted by the notion that tough standards and cooperative efforts would make their assets more valuable. The outage statistics for fossil fuel generating plants and transmission and distribution indicate that significant improvements can be made, and utilities may get important insights from pooling data. But the most significant reason for optimism is that the grid is getting more tightly

integrated every year, and that a problem at a distant generator can cause a cascading failure which blacks out millions a thousand miles away.

The proposed ERO triennial compliance audits are a good and necessary function, although they might be performed more frequently. The procedure for outside evaluation of the compliance audit process is an excellent idea. However, NERC 's proposed penalties (\$1,000 to \$200,000 for violations of its reliability standards) are low. The U.S. Environmental Protection Agency has levied fines of \$25,000 per day for infractions, sometimes totaling \$30 million. The 2003 blackout's cost was estimated at \$6 billion, or 30,000 times the size of the largest ERO penalty. Although provisions are made in NERC's ERO proposal for fine multipliers in egregious cases, the typical fine will probably too low to get the attention of a CFO in a large company.

INPO has recognized that human and organizational performance, and the barriers to good performance, are often the root cause of incidents. The performance of personnel is evaluated during exercises in high-fidelity simulators during biennial plant evaluations. The checklist for evaluation includes organizational effectiveness and performance improvement. Corporate support of operating plants is evaluated explicitly during plant audits. Members agree to certain organizational expectations, such as having the senior nuclear executive in the line organization accountable in an unambiguous way for safe and reliable plant operation.

In contrast, the proposed ERO blackout and disturbance response procedures state that during investigations the focus will be on technical aspects. The guidance given to investigation writers is that the conclusions and recommendations section should address "from a technical perspective, what are the root causes of this blackout? What additional technical factors contributed to making the blackout possible?" with no mention of human or organizational factors.

The ERO should modify its investigation guidelines to stress human factors and corporate support of operational personnel. A wrongly set relay in 1965, an overloaded and under-informed human operator in 1977, a sequence of operator errors and inaction due to lack of data in 2003, and a wrongly cut wire in 2005 should tell us that reliability improvements do not rest on engineering alone, but also on social and organizational science.

## Making electric power more reliable

Currently in the U.S. the cost of unreliable power is demonstrated through buying decisions: one out of every six dollars spent on electric power generation and delivery equipment goes for emergency backups. Improving the reliability of the U.S. electric power system to the levels achieved in Europe and Japan requires a more stringent approach than compliance with consensus standards.

The ERO as proposed is a necessary, but not sufficient, condition for improvement. After the restructuring of the electric power industry, it is difficult to convince a company's CFO to invest in reliability. The ERO will raise the bar modestly, requiring compliance with existing standards. But conversion of voluntary standards to mandatory ones is not likely to lead to the sort of reliability improvement that is needed to bring us to parity with our competitors abroad. To get started quickly, we agree with making the current standards mandatory. However, these initial

standards should be reviewed critically by FERC to ensure that they significantly improve reliability, rather than just ratify the status quo. FERC should in addition require the ERO to create a mechanism that would review all the standards over the next 3 years and propose modifications that would be put to a vote at one time, to avoid standards being set by the most reluctant utility in an area. FERC should also require the ERO to revisit standards on a 3 year schedule to avoid freezing standards at today's level.

An alternative course of action is to wait for the next large blackout, which may lead to Congressional action. Unfortunately, such actions tend to be taken in haste and lead to blunt instruments that sometimes do more harm than good. For example, the 1970 Clean Air Act's vehicle emissions control was needlessly costly to the industry.

Instead, we recommend that FERC provide leadership. FERC should recognize that in a global economy lack of reliable power puts the U.S. at a competitive disadvantage. States should recognize that reliable power may put them at an advantage compared to their neighbors. Reliable power is a public good, no less than excellent highways.

What can be done?

Americans need better information on reliability. In countries such as New Zealand these statistics are available on the Internet. In the U.S. a Freedom of Information Act request is required in many states to get these vital data. FERC should mandate that reliability data be available on the Internet for everyone. Similarly, states should mandate that all load-serving entities provide such data on the Internet.

Overall reliability data is an example of a transparent and easily-understood metric. INPO has found such metrics to be critical to leading the nuclear industry out of the swamp of mediocre reliability. NERC has displayed sporadic commitment to making data on failures available (both to the public and to industry). For example, the database is out of date by more than three years as this is being written. A timely public database of all major disturbances is essential, as are data shared among the industry on equipment and operational failures.

A number of the industry's own comments indicate that the roles of a standards compliance organization and a best practices organization are incompatible. We agree. FERC should require the formation of nationwide best practices organizations that are not a part of the ERO's standards and compliance organization, perhaps constituted as forums with members engaged in like activities (for example, transmission or coal-fired generation). These could be done within the ERO (in a separate compliance function just as INPO is separate from the NRC) or it could be done in an entirely separate organization. We favor the latter.

The best practices organization, rather than the compliance side of the ERO, should continue the readiness audits NERC has begun. It should ensure that these site visits have as their purpose benchmarking each facility against the best metrics found in the industry.

INPO has found experts from organizations such as aviation, insurance, and universities to be effective in providing fresh perspectives. The best practices organization should follow INPO's example, as well as having their own staff experts. In addition, representatives from the technical staff of state PUCs and expertise from operators of the best systems in other countries should be



closely involved in the best practice organization to ensure, on the one hand, that cost and reliability are properly balanced, and on the other hand, that the U.S. is able to take advantage of the expertise that has led to cost-effective reliability elsewhere that is much higher than our own. Equipment manufacturers, ranging from those who make relays and transformers to those who design software, should also be participants in the best practice organization.

In addition to sharing experience about effective maintenance and operational practices (advanced simulator training, storm restoration, etc.), the organization should also share experience and insights about new technologies (such as technologies to monitor, display and control the flow of power, distributed control, automation of failure recovery, improved and lower cost underground equipment).

The ERO will fail to improve reliability significantly unless generators, transmission and distribution owners, and equipment makers are convinced that their companies face huge penalties unless they improve performance. In the current deregulated environment, generators battle for even a slight cost advantage over their competitors and are reluctant to contribute to best practice lists. Thus, any best practice activity will need a firm regulatory incentive to get all parties to cooperate.

FERC was right in September 2005 to ask what lessons INPO can teach the power industry as a whole. The Commission should not accept the view that “nuclear is different,” and should not be content with the easy course of simply designating NERC as the ERO. As presently constituted, such an ERO can do only half the job. If the nation wants to get out of the current reliability mess FERC must do four additional things: 1) require the formation of a nationwide best practices organization; 2) provide strong oversight of the ERO standards to ensure that they will improve reliability in keeping with their new mandatory role, including ensuring that standards are periodically reviewed and upgraded as we learn more about best practices; 3) make reliability data easily available to consumers; and 4) get the attention of companies by imposing significant fines when the lights go out.