During the next few years, the electric power industry in the United States will undergo profound restructuring. The Energy Policy Act of 1992 introduced competition in wholesale power markets, and subsequently the Federal Energy Regulatory Commission (FERC) issued Orders requiring the "unbundling" or separation of generation dispatch functions from transmission services and marketing functions. The North American Electric Reliability Council (NERC) has led industry efforts to make a transition to the regional coordination of system security functions. Regional coordination may require establishing an "independent system operator" to achieve economic power exchanges and reduce line loading problems. Several states, including California, New Hampshire, and Pennsylvania, have already committed to new legislation and/or have introduced regulatory reforms. The other states are following close behind with deregulation and restructuring proposals.

A great deal of attention has been focused on the economic and public policy implications of electric power industry restructuring, and in the wake of the Western system power outages of July and August 1996, many articles have addressed the potentially adverse reliability implications of restructuring. Clearly the new business environment will create not only new forms of regulation and competition, but also unprecedented needs for technological solutions to problems in the areas of systems operations and systems planning.

This paper focuses on the new technologies and techniques that will be needed in a restructured electric power industry. This paper identifies the principal operating changes that will occur and some of the major technological solutions associated with these changes.

The requirements for open access to transmission networks will increase power flows and change power flow patterns. As a consequence, innovative means will be needed for upgrading transmission networks and for using existing networks to their fullest potential. Several individuals and organizations including The Electric Power Research Institute (EPRI) have been placing a significant amount of effort on the development of methods and hardware systems using power electronics to address these needs. Notable in this area is the development of Flexible A.C. Transmission Systems (FACTS). This paper discusses some of the additional efforts that will be needed in this area.

Unbundling and increased competition will require that new information systems be developed both for economic power exchange related functions and for system security related and reliability coordination functions. Improved transducers, data acquisition systems, and expanded or enhanced communications technologies will be needed. This paper provides a status report on activities in this area.
New technical training requirements and engineering analysis tools will be needed in order to deal with system operations challenges posed by restructuring. This paper also addresses the increased complexity and dimensionality of problems in a restructured industry.

**INTRODUCTION**

Legislative and regulatory actions at both the Federal level and the State level are changing the structure of the U.S. electric power industry. Traditionally U.S. electric utility companies have been vertically structured, with "end to end" responsibility for power generation, power delivery, and customer service. Decision making in the vertically structured companies has been regulated by State and Federal regulatory bodies charged with assuring managerial prudence, effective performance, and allowing reasonable returns on investment.

During the next decade electric power industry restructuring will break down the vertical structure of electric utility companies and introduce competition in the place of traditional regulation. This restructuring can be described in terms of moving through the following phases:

- **Phase 1:** Markets for power generation are opened up to non-utility generators. (This phase began in 1978 when the Public Utilities Regulatory Policies Act (PURPA) was passed into law. The transitional problems were essentially resolved with the reforms included in the 1992 Energy Policy Act (EPACT).

- **Phase 2:** Industrial customers will be allowed to "shop for energy." Methods for determining rates have not been established. The FERC advocates compensating utilities for "stranded costs" associated with the old system of regulation. These facilities will not be able to compete with newer, lower cost facilities. Another transitional problem has to do with the possible reallocation of rates among customer classes.

- **Phase 3:** Residential and commercial customers will be allowed to shop for energy. Transitioning to this phase poses significant engineering challenges for several reasons. There will be greatly increased burdens on the grid to accommodate transactions, requiring greatly expanded information systems and more sophisticated control systems. More importantly, to prevent abuses in power marketing, it will be necessary to replace the existing utility operated power pooling operations with a new kind of energy control and "independent system operators."

This paper focuses on the transitional problems associated with moving into the second and third phases of restructuring. When the electric industry provides "open access," electricity rates and system reliability will be affected. Strategies will be needed for coping with the issues identified in Table 1.
### ELECTRIC POWER INDUSTRY RESTRUCTURING ISSUES

<table>
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<tr>
<th>Restructuring Issues</th>
<th>Technology Needs</th>
<th>Specific Requirements</th>
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<tr>
<td>Open Access</td>
<td>Extensive</td>
<td>New Information Systems, Operating Procedures and Analysis Tools for Transaction Cancellation/Redispatching</td>
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<tr>
<td>Stranded Cost Recovery</td>
<td>Minimal</td>
<td>Establishment of Regulatory Rules for Costs to be Recovered and Time Frame for Recovery</td>
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<tr>
<td>Competition for Customers</td>
<td>Minimal</td>
<td>Designing Rate Structures and Identifying Environmental Features Attractive to Customers</td>
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<td>Transmission Pricing</td>
<td>Moderate</td>
<td>Determination of “Ancillary Costs” for Providing Reserves, Maintaining Voltage Regulation, etc.</td>
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<tr>
<td>Assessment of Transfer Capabilities</td>
<td>Extensive</td>
<td>Development of Definitions, Information Systems, and Procedures for Independent System Operators</td>
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<td>Functional Unbundling</td>
<td>Moderate</td>
<td>Separation of Control Center Functions and Adding Equipment to Assure Non-Discriminatory Transactions</td>
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<tr>
<td>New Control Performance Standards</td>
<td>Moderate</td>
<td>Relating System Data to Operating Economics and System Characteristics to Assure Equities</td>
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<tr>
<td>Regional System Security Coordination</td>
<td>Extensive</td>
<td>Expansion of Data Acquisition Systems, Use of New Pattern Recognition Tools, Coping with Increased Dimensionality</td>
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**TABLE 1**

The U.S. electric power industry will be "deregulated" during the next few years. Electric wholesale generators (EWGs) and other non-utility entities will have increased access to power markets, some aspects of traditional regulation will be replaced by competition in an open market, electric utility companies will be required to divest or "unbundle their services," and electricity customers will be able to choose their energy suppliers. What does this mean in terms of needs for new technologies?

First of all, with all due respect to those who have written the myriad of articles on "electric power deregulation," it is probably more appropriate to describe the set of these new
developments as "electric industry restructuring." It is true that some of the regulatory requirements will be reduced, but it is also true that additional and increased regulation will be required, particularly in the case of transmission services.

Apart from the cross currents of simultaneous deregulation and increased regulation, "electric industry restructuring" is a more appropriate term for describing a number of the dramatic changes that have begun to occur. During the last two years, a number of mergers and acquisitions have involved electric power companies and natural gas companies. This trend is likely to continue and accelerate in the future. Currently there are about 200 investor owned electric utility companies in the United States. Industry analysts have suggested that there may be as few as 50 investor owned electric utility companies by the end of the next decade. Examples of the trend toward corporate combinations abound. In November 1996, Duke Power Company, located in North and South Carolina, announced plans to acquire PanEnergy, a natural gas distribution company serving the Northeast and Midwest, and form a new integrated energy company called Duke Energy. Conversely, Enron Corporation, the nation's largest natural gas company headquartered in Houston, bought Portland General Electric, the largest electric utility company in Oregon.

THE MOTIVATION FOR RESTRUCTURING

Why is the electric power industry being restructured? Some say the U.S. electric power industry should be allowed to continue as it is. "If it isn't broken, why fix it?" The United States has one of the best, and in some ways the best, electric service in the world. The U.S. was ahead of the rest of the world in making electric service available to rural areas. The reliability of U.S. electric service is unparalleled. And among the leading industrial countries, the cost of electricity is lower only in Canada, owing to the blessing of numerous large hydro-electric facilities. Moreover, the United States is the only leading industrial country that decreased electricity prices to large industrial customers during the last decade.

The proponents of restructuring support the need for change by pointing out that electricity prices vary widely from state to state, and sometimes even vary widely within individual states in the United States. Some argue that these price inconsistencies were caused by outmoded methods of regulation. The proponents of restructuring go on to say that under a free market, competitive approach, all electric costs can be driven to lower levels and new and improved services can be introduced. The economic and public policy logic is not unlike that used in justifying the changes and deregulation in the telephone industry or the airline industry. (While the economic theories and pricing methodologies may be similar, this paper will point out some significant technological differences that give rise to concerns about system reliability in a restructured business environment.)

THE RESTRUCTURING PROCESS

How is the electric power industry being restructured? Electric power industry restructuring began in 1978 when the Public Utility Regulatory Policies Act (PURPA) was passed into law. PURPA had the effect of encouraging non-utility generators (NUGs) to build power plants.
PURPA also required that electric utilities buy electric power from the NUGs at their "avoided costs." On the downside, PURPA created a number of problems for electric utility companies, but most of these problems have been resolved by new legislation, including provisions in the 1992 Energy Policy Act.

In areas where natural gas was available and cogeneration needs existed, PURPA had a major effect on generation mix, and electric utility power generation planning functions. However, PURPA did not have a significant impact on electric utility transmission planning or operations. And for the most part, PURPA did not affect electric utility dealings with customers.

The second major stage of electric utility restructuring began when the 1992 Energy Policy Act caused the Federal Energy Regulatory Commission (FERC) to focus on wholesale wheeling. Wholesale wheeling refers to the power purchases and sales that take place between electric utilities. The 1992 Energy Policy Act did not set forth requirements for retail wheeling. An example of forced retail wheeling would be when an electric utility company is forced to give a customer access to its transmission system so that the customer can buy power from another utility company.

Restructuring took a giant step forward in 1994 when proposals from the California Public Utility Commission (CPUC) suggested that large industrial customers should be allowed to "shop for energy." The CPUC plan went a step further and also proposed that residential and commercial customers should also be allowed to choose their suppliers. All of this was to be accomplished and put in place within a six year period of implementation. Since 1994 many other states have followed California's lead, and some have even proposed more aggressive timetables for implementation.

The states with the highest rates have, of course, shown the most interest and activity to initiate electric industry restructuring. Notably, New York, Massachusetts, Vermont, and New Hampshire have developed plans or legislative proposals. New Hampshire's House Bill 1392 is representative of current thinking among state policy makers. The bill begins by saying that "the most compelling reason to restructure the New Hampshire electric industry is to reduce costs to all consumers." The bill makes reference to a number of issues including:

- Reliability
- Unbundling
- Customer Choice
- Open Access
- Obligation to Serve
- Environmental Degradation
- Stranded Cost Recovery
- State vs. Federal Authority
- Shifting Costs to Residential Customers

Every one of the other states is at some stage of investigation and within the next five years will probably develop legislative proposals for restructuring. The proposals will address most or all
of the above issues and will include a timetable for implementation. Even the most conservative estimates now anticipate that the massive restructuring of the electric power business will be a fait accompli in the next decade. Some see the changes occurring more rapidly.

Of course, many electric utility companies have entered into this debate, usually focusing primarily on the stranded cost issue and the timeframe for implementation. An example of a "stranded cost," "stranded asset," or "stranded investment" is a power plant which was planned, constructed, and financed under the former system of regulation, but which will not be able to compete if and when the new competitive system is put in place. Many facilities, costing billions of dollars in the aggregate, in effect will be "stranded investments" if open access becomes a reality, as suggested by the California Public Utility Commission and others. The timeframe for implementation becomes a very critical issue from the electric utility point of view, because more time can allow major changes in utility operations and can reduce the stranded cost exposure.

The Electric Utility Shareholders Alliance (Electric USA) was formed in August 1996 to represent the interests of all electric utility shareholders by offering a broad critique of federal proposals that "mandate a sweeping reconfiguration" of the electric utility industry. Electric USA contends that the main street businesses and the millions of ordinary Americans who have invested their savings and pension funds in electric generating and transmission facilities oppose proposals for "federally mandated wheeling" because these proposals will cause significant equity losses. Electric USA has support from more than 150 state and local organizations and from the International Brotherhood of Electrical Workers (IBEW).

Of course many rate payers, including large industrial customers, have a viewpoint which is very different from the Electric USA viewpoint. Many would like to see restructuring accomplished as soon as possible. One of the organizations formed to push for federal legislation mandating "retail competition in the electric utility industry" is the Electric Power Supply Organization (EPSA). EPSA was formed by combining the National Independent Energy Producers and the Electric Generation Association, which had represented separate portions of the independent electric generation industry. EPSA believes that "the moves by the states to require retail competition have increased pressure for a federal requirement for allowing customers to choose the company that supplies them with electricity." EPSA expects federal legislation to be enacted in this Congress or the next.

The Federal Energy Regulatory Commission (FERC) took a leadership role in the restructuring debate with its 1995 Mega Notice of Proposed Rulemaking (Mega-NOPR) and by issuing Orders 888 and 889 in 1996.[2] The most significant points made in the Mega-NOPR were:

- Comparable open access should be allowed in exchange for complete stranded cost recovery. (This has been called "The Grand Bargain.")

- Transmission system operators should be separate from wholesale marketers.
• Real-time information networks (RINs) should be created so that transmission customers have the same access to the same information as transmission system providers.

While these points helped to move the debate forward, they raised a number of unresolved issues, such as:

• Defining what is meant by comparable open transmission access, particularly when power pools are involved.

• Precise mechanisms for determining the stranded costs to be recovered.

• How can functional unbundling be best accomplished to separate transmission system operators from wholesale marketers? Is divestiture necessary and/or is it necessary to have independent system operators (ISOs)?

• Allocation of the costs for the real time information networks.

• Will the reliability of the system be degraded from new demands being placed on the transmission grid or from the increased complexity of system operation?

FERC Order 888 requires utilities that own, control or operate transmission systems to file nondiscriminatory open access tariffs to provide others the same electricity transmission services that they provide to themselves. This concept was introduced in the earlier FERC Mega-NOPR. In effect, Order 888 opens wholesale electric power sales to competition.

FERC Order 889 issued on April 24, 1996, the same day as Order 888, requires a real-time information system to assure that the owners of transmission systems and their affiliates do not have an unfair competitive advantage in using transmission systems to sell power. Again, this concept was introduced in the earlier FERC Mega-NOPR, but the language in the order is somewhat more precise and clearly includes affiliates along with the owners of transmission systems.

On the U.S. Congressional front, a number of legislative proposals are being considered. Representative Dan Schaefer of Colorado who chairs the House Commerce Subcommittee on Energy and Power has proposed legislation (HR 3790) that urges the states to step up their efforts to deregulate the electric power industry and sets a deadline, December 15, 2000 for implementation. Schaefer hails deregulation as a great boon to the American economy and he claims that it will spur competition, lower electricity prices, and create jobs. Electric USA and the Edison Electric Institute have faulted the bill for offering unrealistic promises to average consumers, overrunning current state efforts, and allowing large industrial customers to benefit at the expense of residential and small business consumers.

Representative Michael D. Crapo is among a minority of members who have stated that deregulation will raise electricity prices.
Former Senator Johnston advocated comprehensive federal legislation to restructure the electric power industry. In remarks made to the Electric Generation Association on January 22, 1996, he said that competitive markets save society the costs of unneeded regulation. Senator Johnston has focused on the state/federal balance issue and he has stated that the balance can be maintained if the states establish competitive wholesale power procurement markets and establish retail access for all customers. Senator Johnston has expressed concern about utilities favoring their own generation, but he supports full stranded cost recovery. His support for full cost recovery is based on recognition that governments encouraged utilities to promote nuclear generation and other decisions that now could lead to bankrupting utilities under a fully deregulated competitive scenario.

There are differences of opinion about how soon federal legislation may be enacted. Senator Murkowski, who chairs the Senate Energy Committee, says there should be no rush to pass federal legislation until the transition to wholesale competition has had time to evolve. Representative Biley, in remarks to the Federal Energy Bar Association, has called for hearings to begin soon. The IEEE-USA Legislative Report Newsletter predicts little or no action on utility deregulation in 1997. This prediction is based on the expected slow downs associated with the changeover in President Clinton's administration as many cabinet and agency heads are being replaced.

While the federal government prepares to resume the debate, the electric utility industry is preparing to deal with a number of technical problems and challenges. The North American Reliability Council (NERC) and the Electric Power Research Institute (EPRI) are focusing on the adequacy of transmission capacity and transfer capability determinations. Both organizations have also been asked to investigate various aspects of the recent power outages in the Western power systems.

There are serious technical concerns about power system reliability in the future.\[3\] Generation capacity reserve margins are declining for the following reasons:

- The power plants built in the middle 1960s or earlier are reaching the end of their useful lives. Some of these plants are being retired and others have been derated. Life extension and uprating efforts are being undertaken in some cases but the net effect is reduced available capacity.

- The amendments to the Clean Air Act and other environmental requirements are resulting in plant retirements or the non-use of coal fired units. Some of these coal fired units are 500 megawatts or larger. Hence, a significant amount of generating capacity is unavailable for environmental reasons.

- Industry restructuring and the trend toward increased competition is forcing the retirement of units that are not competitive from an operating cost point of view. There is uncertainty about the treatment of "stranded assets," but unquestionably some of the stranded generating assets will be removed from service.
Electric industry restructuring has stimulated the construction of non-utility generation or exempt wholesale generation (EWG), but has reduced the construction of new utility owned generating capacity. During the period of transition to increased regional coordination, capacity may not be built where it is needed and when it is needed.

Transmission capacity reserve margins are also declining. The reasons for this decline are:

- Restructuring is increasing the number of transactions and the amount of power purchased and sold over innerconnections. Transmission systems were designed to accommodate the amount of wheeling associated with the former system of regulation (vertically integrated utilities serving franchise areas without open access).

- New transmission lines face a great deal of environmental opposition. Not only are individuals and groups concerned about aesthetics and electrical safety, but increasingly there is a concern about adverse human health effects from electric and magnetic fields (EMF). The Electric Power Research Institute and other research organizations have found ways to reduce transmission line fields and improve aesthetics and address safety considerations. However, the costs associated with these methods are significant.

- Uncertainties about industry restructuring and the trend toward increased competition discourage the construction of new transmission lines. Transmission is a very expensive, high risk investment. As in the case of generating capacity, during the period of transition to increased regional coordination, transmission capacity may not be built where it is needed and when it is needed.

While relatively minor improvements are being made in the equipment for generating and transmitting electricity, major improvements are being made in the information technologies used to monitor and control market transactions and power flows.\[4\]

- The hardware and software used for data acquisition has become much more sophisticated and much less expensive. Electric utilities are installing fiber optic communication systems with new transmission construction and along existing transmission corridors. Fiber optic methods compliment existing extensive communication systems comprised of power line carrier, microwave communication, and radio/wireless systems. Research efforts have focused on improved database management and open systems approaches to reduce the costs of telecommunications functions.

- The cost of computers and data processing power has reduced exponentially in the last decade. This cost reduction, along with advances in operating systems and improved application software, provides a powerful platform for the power system operation tools and analytical capabilities needed to address the transition
problems associated with restructuring. Information technologies will make it possible to develop more cost-efficient and environmentally-effective methods for power generation, by reducing the losses associated with the transmission of electricity, and by designing power systems that accommodate increased economy interchange and facilitate environmental dispatching.

- Updated base-line information and forecasts for the next decade on the environmental impacts, costs and availability of conventional and unconventional energy production systems is needed. Particular emphasis should be placed on opportunities for the increased use of combined cycle natural gas generation, wind energy, solar thermal energy, and photovoltaic energy.

- Current public policies and possible policy initiatives should be examined for all of the power generation and energy storage technologies. As the electric utility industry transitions toward a market-driven competitive approach to power generation, there is a possibility that long-term cost-effectiveness may be sacrificed for short-term economies. In addition, there are indications that some of the environmental programs that have been initiated by state public service commissions may not be continued with a restructured regulatory approach.

- With increased "wheeling," the losses associated with the transmission of electricity may become more significant. However, new technologies such as flexible A.C. transmission systems (FACTS) and unified power flow controllers (UPFC) are currently being developed to reduce losses in individual lines and to give power system operators increased control over power routing. There is a need to develop data and forecasts concerning these technologies as a basis for influencing future technical and policy decisions. Several specific design concepts will be considered including the cost and value of replacing mechanical switching systems with new power semiconductors, and the cost and environmental impact of using new materials and new configurations for transmission line design.

- The unbundling of power systems services and the transition to having an "independent system operator" will create opportunities to redesign power system operating procedures to accommodate increased economy interchanges and facilitate environmental dispatching. There is a need to compare the informational requirements and operational guidelines currently used in utility power control centers with the requirements and guidelines that will best serve the public interest when independent system operators assume the responsibility for economic dispatching decisions. It will be important that redesigned systems and procedures properly incorporate the need for maintaining power system reliability and power quality.

- Each of the existing energy control center applications will need to be redefined for the restructured industry to function effectively. Existing energy control center
applications include economic and environmental dispatching, automatic
generation control, unit commitment, interchange evaluation, power flow,
contingency analysis, state estimation, supervisory control and data acquisition.

There is a need to develop improved methods for automatic generation control in
a restructured industry and begin the development of more specific proposals and
research plans for redesigning each of the other existing energy control center
applications.

There are differences of opinion about whether changes in industry structure had a role in causing
the Western system blackout.\cite{5}

Unquestionably, with increased "wheeling," the losses associated with the transmission of
electricity may become more significant. However, new technologies are currently being
developed to reduce losses in individual lines and to give power system operators increased
control over power routing. There is a need to develop better data and forecasts concerning these
technologies as a basis for influencing future technical and policy decisions. Several specific
design concepts are now being considered including the cost and value of replacing mechanical
switching systems with new power semiconductors, a technology called FACTS (Flexible A.C.
Transmission Systems). Consideration is also being given to using new materials and new
configurations for transmission line design. In addition, several reports have been published on
the potential for upgrading existing transmission lines.

The unbundling of power systems services and the transition to having an "independent system
operator" will create opportunities to redesign power system operating procedures to
accommodate increased economy interchanges and facilitate environmental dispatching. There is
a need to compare the informational requirements and operational guidelines currently used in
utility power system control centers with the requirements and guidelines that will best serve the
public interest when independent system operators assume the responsibility for economic
dispatching decisions. It will be important that redesigned systems and procedures properly
incorporate the need for maintaining power system reliability and power quality.

As restructuring is implemented, each of the existing energy control center applications will need
to be revised, and in some cases totally redefined, for the restructured industry to function
effectively. Existing energy control center applications include economic and environmental
dispatching, automatic generation control, unit commitment, interchange evaluation, power flow,
contingency analysis, state estimation, supervisory control and data acquisition.

**OPPORTUNITIES**

The opportunities associated with open access have to do with the various options for reducing
energy costs or preventing the future increase of electricity rates. The options are summarized
here:
• Negotiate favorable long-term contracts with existing energy suppliers during the period when new legislation is being considered. (This has been the strategy of the big three auto makers in their Michigan operations.)

• Promote legislation that encourages multiple energy suppliers to compete for industrial customers, then select lowest cost offerings. (This is the strategy advocated by the Electric Power Supply Association and others.)

• Purchase or construct electricity generation facilities and become a "self-generator" for some or all of your own needs or even become an "electric wholesale generator" selling power into the grid for profit.

THREATS

The threats associated with the new business environment have to do with the possibility of reduced system reliability or increased energy costs as a consequence of strategic decisions. The options available to prevent or mitigate these threats are:

• Assure that reliability is adequately addressed in new contracts for energy supply.

• Promote legislation and regulatory reforms that address reliability, supply adequacy, and power system security.

• Recognize that a new system of marketing or self-generation options will not necessarily reduce energy costs or provide sufficient levels of reliability. (This is the position taken by the Electric Utility Shareholders Alliance).

CONCLUSION

There are obviously many concerns associated with restructuring that have been considered to be outside the scope of this paper and have not been addressed here. There are concerns that restructuring will cause an end to some of the programs currently funded by utilities that provide elderly and low income customers with assistance, there are concerns that research and development will not be supported, and there are concerns that some of the existing programs in support of environmentally preferred technologies will be discontinued.

To conclude with an understatement, the next few years will certainly be interesting. The forces of change have been unleashed and the effects will undoubtedly be profound. It will be important that all electricity consumers stay apprised of new developments in the area of electric power industry and carefully evaluate strategies for coping with restructuring.

REFERENCES


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