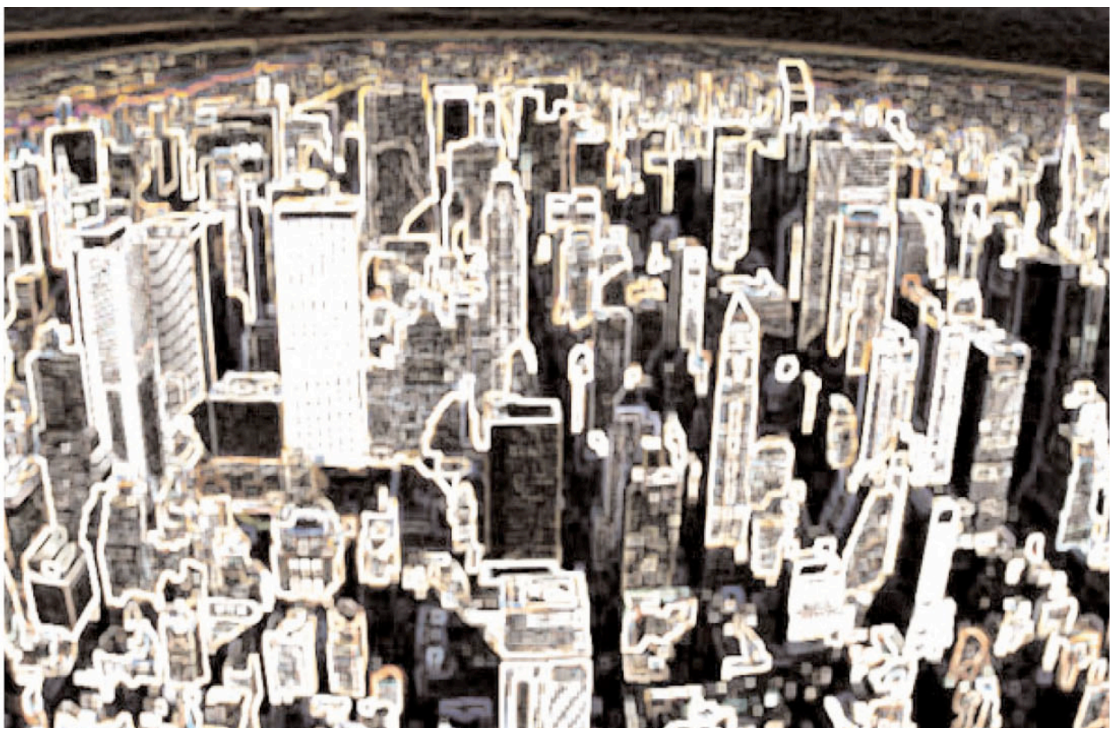
Secure Wattage Where It's Needed

(Follow-on to Op Ed piece, The New York Times, June 6, 2001)

Dr. Roger N. Anderson
Doherty Senior Scholar
Lamont-Doherty Earth Observatory
Columbia University
New York, New York 10027
anderson@ldeo.columbia.edu

"Electric power systems are prototypical socio-technical systems, meaning that their technical, social, economic, political, and cultural elements are tightly interwoven and impinge directly and forcefully upon each other." (National Science Foundation/Office of Naval Research solicitation 2002-041).



Power consumption in New York City on a recent winters night --

The terrorist events of 9/11, when combined with the power shortages in California last winter, suggest that we as a country are not well prepared to meet what is sure to be a growing threat to our ability to deliver electricity where its needed, when it is needed, in the future. Even though New York City saw an immediate 140 megawatt (MW) drop in electricity demand and a total net reduction of 90 MW with the destruction of the World Trade Center, that was only about 20 percent of what was predicted in some early reports (Power Alert II: New York's Persisting Energy Crisis, New York Independent System Operator (NYISO), March, 2002).

NYISO[1] warns that the state must add more than 7,000 MW of new generating capacity by 2005 to avoid serious shortages, enough to supply more than 7 million homes with electricity. "New York remains headed toward a very serious power shortage unless it acts immediately to get new supply sited and actually built within its borders," said William Museler, CEO of NYISO (Reuters, March 27, 2002).

We Really Do Need an Energy Plan

But New York and California, let alone the rest of the country, cannot afford unreliable distribution of electricity in this time of national crises that seem to continue to spiral. The burden of developing an efficient modernization plan must be shared by not only City, State and Federal governments and the power and generation companies that make their profits buying, transmitting, and selling through the electricity grid – the responsible parties pre-9/11— but the cause must now also be taken up by we the citizens because it is so critical to our "pursuit of happiness".

In particular, computerized controls, called Power Control Systems (PCS) that control the production and distribution of electricity throughout the country will have to be very much more sophisticated than at present. For one thing, it will take a whole new generation of technologies to unite the computer control systems of the electricity grid into a single integrated whole. Luckily, much of this control systems technology has been developed recently by the aerospace, automotive and manufacturing industries. The task at hand is its adoption by the electricity industry. That, in turn, will require experts and expertise imported into a corporate and governmental culture bred out of the electrical utilities of our grandparents: one that is notorious for being insular and slow to respond to technological change.

But an efficient electricity grid is a necessity if we are to prevent metropolitan shortages. We have plenty of power generation capacity online in North America, but with energy-hungry demand concentrated in cities, and far from the mostly rural power generators, urban shortages are sure to increase. As NYISO warns, California's difficulties will likely spread to other parts of the country even without terrorist targeting. Both New York and California have difficulties with construction of new gas-pipeline and power-transmission feeder systems, and therefore have significant choke points in their electrical grids, and both are prime terrorist targets.

9/11 has emphasized the need to fix the electricity distribution system **before** demand seriously overwhelms supply a few years from now. With this need in mind, I have been reviewing the state-of-affairs of Power Control Systems within the present power industry, and comparing it to more modern, integrated command-and-control systems in other industries. There is little doubt that the system is "broken" and that the fix will not be easy.

Your Grandparent's Power Control System

A Power Control System of unprecedented scope and reliability will be required to distribute electricity quickly and efficiently in the future. Developing it makes

[1] NYISO is a not-for-profit corporation established in 1999 to help restructure New York's electricity industry. It oversees the state's wholesale energy markets and runs its high-voltage electric transmission system.

updating our air traffic control system look like child's play. It is not a matter of simply joining the systems that currently run the regional grids in North America. Fixing the NYISO problem is not enough. As the Pentagon found out in trying to integrate computer systems from the different armed forces into unified, battlefield "Infosphere" command-and-control systems, predictability declines as the integration tasks become more and more non-linear. Breakdowns occur that have not been foreseen from historical experiences with the smaller, more linear systems that in the past acted independently.

The PCS of your local electric utility and ISO are really very simplistic. Since consumption is not known second-to-second (meters are not analyzed for consumption patterns, but are instead used entirely for billing), the computer merely balances the spin of power generator turbines under its control to keep the Alternating Current (AC) of the grid at as close to 60 cycles per second (Hz) as possible. Any less and the computer revs up the Revolutions Per Minute (RPM) of turbine generators; any more and the computer sells the excess power to the regional grid through brokerages that buy and sell units of power. Too out of balance on the positive side and expensive internal generators held in reserve must be spun up. Too negative, and expensive purchases from external suppliers must occur.

The problem is that both the software and hardware of the PCS were designed (and often built) decades ago under the assumption that excess power would always be readily available from other utilities on the regional grids. If the computer didn't have enough generators to meet demand, it would purchase electricity from the regional grid at a fixed price. With de-regulation of the electricity industry, thousands of independent electricity producers are popping up all over the country to sell expensive power at times of peak demand, and choke points exist at critical and varying junctions of the electricity grid all over the nation (e.g., see WSJ, Dec. 20, 2001).

Our electrical power grid is managed by an antiquated and cumbersome, predominantly linear, PCS called a "point-of-control" system. Unfortunately, it is ultimately a significant threat to our national defense, let alone to our capability to deliver reliable power in times of peace. A much more sophisticated, integrated PCS capable of dealing with non-linearity (chaos) in the system is needed. For example, there are few large-scale systems integration tools available to Electric Companies and ISO's such as training simulators, neural nets, artificial intelligence, optimized traffic schedulers, and those that have been developed by suppliers are difficult to sell into this most conservative electricity industry.

Most glaring of all, electronic switches, called **Thyristors**, that divert current from one path to another in much the same way that transistors channel 0's or 1's in computers are available to manage the flow of electricity around transmission grid choke points, but they are expensive, and again, have been slow to be adopted by the conservative power industry (c.f., MIT Technology Review, A Smarter Power Grid, Peter Fairley, July/August, 2001).

As the electricity grid becomes more and more complex and non-linear, and as connectivity increases with time, it will become more and more difficult for human operators to control. Who will decide where the power shortages go? Or whether scarce natural gas goes to heating or lighting homes? And as California's citizens can attest, woe to us if electricity demand truly gets ahead of supply.

Below, I describe the current PCS of a modern power company. To be good citizens, we really do need to know how the electricity business works, if not what electricity actually is and how it is produced and distributed. Then I will offer my favored solution to the problem – adoption of a computerized business control system developed for other industries that simultaneously computes the twin demons of optimization: minimizing costs while maximizing efficiency of production and delivery.

How Does A "Modern" PCS Work?

Since 9/11, I have conducted a detailed analyses of current and planned technical improvements in the transmission and generation Power Control System of a major regional electricity supplier considered by Wall Street to be a technological leader in the electricity industry. The grid under its management supplies a major urban area of the United States (not New York City) that includes more than 5000 square miles and several million people.

This PCS is operated and supported 24 hours a day, 7 days a week, by approximately 100 conscientious and well trained people. Its mission is to balance loads among private consumers, businesses, and industrial users against the various generation resources available to it, both from internally owned generators and from external purchases available through company's trading floor. If its internal generation resources do not satisfy the instantaneous load at any given time, the company buys power across its interconnections to the North American Transmission Grid (called the Interconnect).

The inflow and outflow of electricity is monitored in real-time at all Interconnect sites and at critical junctions of the company's own transmission lines. The data are transmitted to the PCS every 2 seconds. Simultaneously, real-time costs are computed for all generators used to produce power for the company. A diverse mix of natural gas, coal, oil, and nuclear energy, in turn, fuels these. Costs to produce power for all generator and fuel combinations are constantly compared with spot prices available from suppliers. The PCS automatically selects the cheapest alternative at any time for adding power to the grid, and either increases the spin of its reserve generators, or alerts its traders to buy cheaper power from grid brokerages.

In addition, the PCS currently manages a one-way, real-time Supervisory Control and Data Acquisition (SCADA) network that sends an additional 230,000 measurement inputs to the PCS every 30 seconds. Problems appear if the frequency of the AC in the transmission grid begins to drop below 59.99997 Hz (five nines) for computers, and below 59.997 (three nines) for electric motors, and "all hell breaks lose" to quote an operator from the PCS.

For emergencies such as these, the PCS has computerized controls that extend directly into major business customers' circuit breakers for computer banks and expensive electrical equipment, but the company always hopes it has time to call the customer first before shutting down their equipment remotely – a rarity.

Consequently, when the frequency begins to vary by even a few hundredths of a cycle per second, the spinning reserve of the company – kept ready for increases in RPM's to add power at any time – is used to stabilize the power in the company's grid. This "emergency" power comes at a higher cost than the "baseline" units that are run 24/7 at their maximum spin to provide the stable supply for the company. For example, a reserve natural gas generator may be run all day every day to produce 600 MW, but its spin is increased to produce 700 MW at peak consumption times. In contrast, all the company's nuclear generators are run full-out, 24/7, and they form the baseline power of the company. Why, because of their cheap cost per MW. The company has two nuclear generators that produce 2500 MW of baseline power at a cost of only $12.50/MW. Once the high Capital Expenditures (CAPEX) or "sunk cost" for construction have been recovered, nuclear generators are cheaper and more stable than gas, oil or coal fired plants to operate because they don't require the environmental air quality scrubbers that the latter do, and because of the highly variable commodity prices for fossil fuels, and because the government subsidizes nuclear waste disposal. No renewable sources such as wind are currently used because they cost $25 to $30/MW in the company's area.

The major drivers to operational costs of the company are Operations and Maintenance (O&M) of its facilities. Overhauls of generators and reconfigurations and modernizations of its power grid must be scheduled well in advance and coordinated with other regional suppliers in order to be transparent to customers. Software updates must be handled with particular care. The business is profitable because the company makes approximately $50/MW from normal sales, and occasionally, high demand sales have gone to $2500 to $3000/MW in recent years.

The Current PCS Management

The physical lay-out of the PCS was state-of-the-art in 1988 when it was built, with the company surveying operating conditions at 12 other control centers around the U.S. before settling on its design. By 2000, the ergonomics of the controls were still very good, but the computer software and hardware in use became antiquated and obsolete. The company was still serving its PCS with a mainframe, but with the total redundancy in hardware and software required, that became prohibitively expensive. The company that produced its mainframes even went out of business, and the company's software vendor reluctantly picked up maintenance. Data were stored in a proprietary database that was not compatible with Oracle and other widely used industrial databases.

The company upgraded the PCS computer systems in 2001 to a client-server, UNIX architecture, supported by an Oracle database, and modern graphical User Interfaces (GUI). However, the networkability of the system still leaves something to be desired. Its Ethernet is just now being upgraded to 100Mbps, and top management for perceived security reasons forbids use of the Internet for communications with the field and its own SCADA systems. The company Intranet is primitive at best, and no Microsoft products are found in the PCS at all (perhaps the last remaining industry for Bill Gates to conquer).

In addition, several "Soft Side" people-to-people issues were uncovered by the modernization. The upgrade did not include input from the company's operations group at all; instead it originated in Information Technology (IT) department through the Chief Information Officer (CIO). He bought from a known and comfortable supplier – the one who had serviced the previous software. "Staffing concerns" were the excuse given by top management when protestations of lack of inclusion by the PCS operations people were voiced. Dispatchers actually boycotted design meetings for the new system in frustration. This resulted in the operations group then being included in reviews of prototype systems – at the contractors' insistence.

As a consequence of these "turf wars" (as the company's top management called them), users are NOT utilizing many of the new features of the PCS software system. For example, the 2001 software design supports interoperability between the two types of UNIX workstations: one to control interaction between the company and outside power suppliers, and one for control of internal company power distribution. Operators of one system cannot call up or interact with the other. Operators are trained to operate both systems, and they do rotate from one to the other on a regular schedule, but they are not allowed to let the computers communicate.

Most operator tasks are not automated within the PCS, but depend upon the experience and awareness of the people themselves. The operational processes of the staff are procedure-based and well-documented, but are available only in paper manuals. The company does not use new software capabilities available for automating alarms work-tag tracking, and the opening and closing of circuit breakers remotely. No trend analyses or problem resolution is done computationally, nor is a data historian used (common practices in other industries). Data from the warehouse appears to have never been looked at more than a month into the past.

Work orders to substations and power linesmen is created on a computer, printed out, and then FAXED to the field offices by the PCS operators. These work orders are not tracked further by the PCS, although it has the capability to manage electronic work orders and automatically send e-mails.

Perhaps more critical in today's world, while there is an excellent and well practiced plan for restoration of services from natural disaster outages (common), there is still nothing about terrorism (not yet anticipated seriously when the procedures were last updated in 2000).

The "technology cycle" for new computer software and hardware (still paired) has historically been 14-16 years, with the latest upgrade the most rapid in company's history (1988 to 2000), so the PCS operators are bracing for a "long next few years" and the software vendor lamented the "incredibly long sales cycle in the power industry."

Use of Simulators in the PCS

Expert Systems and Artificial Intelligence (AI) technologies for the complex scheduling required for power management "were looked at years ago by IBM. They tried to develop a prototype system. However, IBM declared their process to be too complex, and moved on to easier markets." (This analysis was done in 1985, and the power company still considers it valid. IBM's opinion is that they tried to develop a prototype of too much of the operations at once, back then. New neural network and data mining technologies should make this a very doable task in today's computational world.)

Optimization within the PCS is a manual process executed by experienced personnel without computer help. Independent power suppliers have made the optimization job extremely difficult as the market is being deregulated. The company is now required to transmit additional power generated by independent generation companies to their customers, as well as pay the independent for any power that the company uses for its own customers. At the same time, brokering processes have exploded in complexity and speed, and even with the collapse of ENRON, the work required to buy and sell power back and forth between grid members has grown exponentially.

Training has become a special issue: the operational staff – too busy, has erratically attended organization, and training sessions. The PCS SCADA data used for training must be real-time, and cannot be replayed for instructional purposes. No case histories are used. There was no training simulator in this software update cycle, a casualty of budget cuts. The cost to maintain an up-to-date simulator became too high because of the rapidly changing configuration of the national power grid, and particularly of the rapidly expanding power input into the company's grid from independent power producers, and customer co-generation facilities as the result of de-regulation. It is ironic that the added complexity of the system made the keeping of an accurate computer simulator expendable. That would be like an aerospace company saying that its new planes are too complex to create a training environment for pilots -- other than flying the machine itself.

It is particularly scary in the high pressure PCS environment because operators must quickly assess the need to disable power to any section of the grid from the appropriate displays on their workstations. The added unpredictability of terrorism should instead make simulation even more critical to the PCS.

Also, systems process drawings are still kept on large wall charts that are revised by real draftsmen. And risk management is not formalized through the use of any software at all, but is established in the form of best practices operations that are maintained using training manuals.

On the good side, the company has intentionally placed great responsibility and power in the hands of the PCS controllers, and they are well compensated for it. Being a controller is a "star" appointment, and job attrition is very low. Controllers are highly skilled and very attentive. They usually have 2-3 years of college education, and stay in the job 20-30 years, routinely. They do a good job when all is well with the national grid.

Planning has improved since the addition of a full time scheduler (in the 1970's) and a PCS coordinator (1980's). There is now under development an on-line flow chart with procedures for how to do certain critical tasks, and how to respond to certain specific situations (usually weather related outages). And there is an automatic pager system to notify off duty employees of crises.

A Vision of the Next-Generation Power Control System

No question the PCS can be better supported by machine computation, but the operators remain unconvinced, even as their jobs become more and more difficult. In particular, few PCS simulation environments exist to train new engineers and managers about how to respond to crisis scenarios. The case study revealed that fault detection and tracking of what has failed, where, and when, remains dependent upon operator experience and "instinct".

On the consumer side, there is no easy way for most users to track their energy consumption on a real-time basis or prepare the usage profiles necessary to identify steps that could be taken to cut costs. Except for the largest industrial users, consumption data is not currently available except on an after-the-fact basis, and after the end of each month, at that. Further, even that information is highly fragmented, since most utilities treat each meter as a separate account. As a result, it is a major undertaking simply to compile data regarding historical or Geographical Information System (GIS) usage, as generally required at the time of any competitive procurement in most other industries. The irony is that the benefits from operational, environmental and cost visibility can be easily computed and demonstrated in economically believable terms in the PCS Simulator, if the company had one.

So, Where's The Optimism?

The incentive for change got a significant boost since 9/11. Many consumers, big and small, are taking steps to modernize the collection, tracking, and analysis of their electricity consumption, with or without the power companies. Forever gone are the days when Americans know that their electricity will be stable and cheap. Energy prices are already fluctuating wildly, and may soon be manipulated by terrorists – the grid is unquestionably on target lists. Yet the world yearns for abundant and cheap electricity, and most don't yet have it, as can be seen from the satellite collage of night on Planet Earth. Bucking this trend, the current Power Control System of your local electric utility and Independent Services Operator is frighteningly simple and must be modernized.