TOM CASTEN • PERSPECTIVE

Fundamentally, there are two ways to prevent future electricity blackouts such as those that affected north-eastern US and parts of Canada in August. One is to spend billions on new wires; the other is to save money by encouraging the use of decentralized energy. Tom Casten says that the latter would not only be more successful, but would also deliver a host of other benefits.

Preventing blackouts

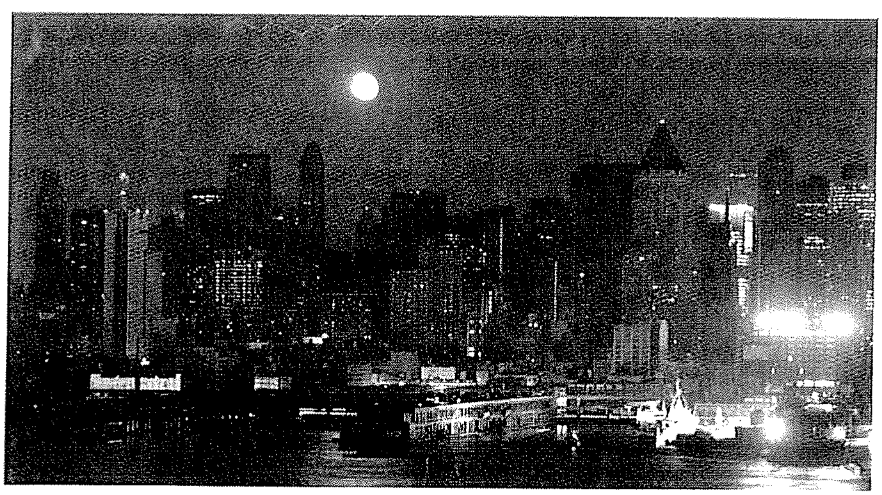
On 14 August, at around 2:00 pm, a 31-year old, 650 MW Ohio power station failed. Transmission controllers struggled to route power from remote plants, overloading transmission lines. At 4:06 pm, a 1200 MW transmission line melted, starting a failure cascade. Lacking local generation, system operators could not maintain voltage and five nuclear plants tripped, forcing power to flow from more remote plants, and overloading regional lines. By 4:16 pm, the north-eastern US and Ontario, Canada lost power.

This was the eighth major North American outage in seven years, not counting five localized blackouts in New York City and Chicago. These area-wide failures began in 1996 with a blackout of 18 western states, followed by a 1997 ice storm in Quebec that knocked out much of New England, and a 1998 tornado that crippled mid-western power systems.

Then there was the California system failure in 2000, three ice storms in Oklahoma, and the August 2003 blackout. Pundits spread blame widely and call for massive investment in wires, while ignoring the fundamental flaw – the excessive reliance on central generation of electricity.

Power system problems are deeper than repeated transmission failures. Many US generating plants are old (average age 35 years), wasteful (33% delivered efficiency) and dirty (50 times the pollution of the best new decentralized energy plant). Centralized generation, besides requiring ugly, highly visible transmission lines, does not recycle its own by-product heat or extract fuel-free power from industrial waste heat and waste energy. This leaves two starkly contrasting ways to address blackouts:

- spend billions on new wires: this won't completely eliminate blackouts and will exacerbate other problems



Upper West Side of Manhattan in virtual darkness, 14 August. Any lights were from emergency power supplies (AP/George Widman)

- save money by encouraging decentralized energy; this will greatly reduce system vulnerability and deliver a host of other benefits.

DECENTRALIZED ENERGY COULD HAVE PREVENTED BLACKOUT

Years of active discouragement of all local power by the Ohio and Michigan utilities left the grid vulnerable to sagging voltage. Local generation can alter its output automatically to support voltage and enable lines to carry full design power.

In neighbouring Indiana, NiSource encouraged local power at the steel mills that it serves. It formed an unregulated subsidiary in 1994 that invested over US$300 million in 460 MW of decentralized power. The subsidiary, Primary Energy, built five projects that recycle waste heat and normally flared blast furnace gas. All of the power is consumed at the steel mills, easing transmission congestion and supporting local voltage.

The Indiana steel mills collectively save over $100 million per year by producing power with waste energy

Had the Ohio and Michigan steel mills recycled energy to produce on-site power, the plants would have supported the voltage and allowed the wires to carry more power to other consumers. All other things equal, the blackout would not have occurred.

Furthermore, such actions are good for the economy and the environment. The Indiana steel mills collectively save over $100 million per year by producing power with waste energy. These decentralized energy projects produce no incremental emissions and displace the emissions of a medium-sized coal-fired station operating around the clock. They are the environmental equivalent of roughly 2500 MW of new solar collectors operating for 20% of the time, on average.

These projects have not hurt the local utility, Northern Indiana Public Service Company, on balance. Yes, the utility sells less electricity to the mills, but steel production has risen, requiring more shifts and pumping up the local economy, increasing other electricity sales.

Decentralized energy (DE) has come of age. It employs proven central generation technologies and fuels but is located next to electricity and thermal loads. DE power goes directly to users, by-passing transmission, and DE plants recycle normally wasted heat, saving fuel and pollution. Local generation options are technically ripe, environmentally superior, and at least twice as efficient as average central generation.

Unfortunately, laws and regulations block decentralized energy. The industry and its regulators are caught in an overloaded, wire-entangled web that blocks innovation.

THE WIRING OF AMERICA

Central generation – long considered optimal – is an outgrowth of early generating technologies. Hydroelectric plants were inherently remote and early coal plants were noisy and dirty – not good neighbours. And coal plants required skilled operators, making them inappropriate for smaller users. For 80 years, power from remote plants – linked to the user by an ever growing set of wires – enjoyed cost advantages over local power.

By contrast, transportation required small engines that did not need skilled operators. Coal was tried for automobiles (the Stanley Steamer), but was soon displaced by oil-fired piston engines. For the first six decades of the 20th century, power technology evolved along two separate paths – coal-fired steam turbines for electricity and oil-fuelled piston engines for transportation. Over time, engine-driven power plants became cheaper to build, but required more expensive fuel and were only economic for back-up or remote electricity generation. Coal-fired steam power remained a better value for electricity into the 1960s.

Aircraft needs spurred another power generation technology, the combustion turbine. Pioneered near the end of the Second World War, early combustion turbines lacked efficiency but produced more power per unit weight than engines – critical to aircraft. Technology marched on. By the early 1980s, combined cycle gas turbine plants had become more efficient than the best steam power plants. To fill the gap being left by environmental pressure on coal plants, turbine manufacturers developed turbines suitable for stationary power generation.

By 1980, local gas turbine generation cost less to install and operate, required less net fuel and produced fewer net emissions than the best possible remote gas turbine generation and associated wires. Turbines are available from sub-megawatt to 200 MW in size, appropriate for local loads; the plants are all automated, clean and quiet. Generating power locally avoids capital required for transmission lines and eliminates transmission losses. Local power plants, unlike remote generation plants, can recycle by-product heat, reducing net fuel use and cost. The power industry embraced turbine technology, but clung to central generation, missing opportunities to save money and pollution with decentralized gas turbine generation.

Many other trends of the past 30 years also make decentralized energy attractive. The electrical efficiencies of turbine and piston engine power plants continue to increase. Transmission system losses of remotely generated power have increased from 5% to 9%, due to congestion. Computer controls enable unattended local generation based on waste gas and waste fuel.

The most efficient generation technology ever invented, back-pressure steam turbines, were historically limited by operator needs. With computer controls, these devices can economically extract power from waste heat, waste fuel, and steam pressure drop in virtually every large commercial and industrial facility. The US currently vents or flares heat, low-grade by-product fuel and steam pressure drop that could support 45–90 GW of back-pressure turbine generation capacity – some 6%–13% of the current US peak load.

Even coal-fired local power now beats the costs of power delivered from remote coal plants. Advances in fluidized bed boilers enable on-site production of heat and power with coal, biomass and other solid fuels in environmentally friendly plants. The limestone beds chemically bond with sulphur as calcium sulphate and limit combustion temperatures, reducing NOx formation. These clean coal plants, located near users, recycle heat to achieve 2.5 times the efficiency of remote coal plants.

Given all of these advances, an optimal power system would generate most power near users, using existing wires to shuttle excess power. Because electricity flows to the nearest connected users, regardless of the sales contract, locally generated power by-passes transmission lines.

Which brings us back to those long protected, overburdened, and vulnerable, failing wires that connect remote central plants to customers. Although the power industry finds itself in trouble, it clings to yesterday's optimal approach. Every stakeholder pays.

Power prices shot up by 65% from 1968 to 1984, needless environmental damage continues, many major industry players have declared bankruptcy or are close, banks are saddled with billions of non-performing loans to new central plants, and blackouts have become a way of life.

ELECTRICITY REGULATIONS AND INDUSTRY RESPONSES

Competition cleanses, discarding firms that cling to yesterday's technology. But the electricity industry has long been sheltered from competition. The US electricity industry's guiding signals have, since 1900, come from regulation rather than from markets. All 'deregulation' to date has left intact universal bans on private electric wires and many rules that penalize local power generation and protect incumbent firms from cleansing competition. History sheds light on how and why utilities and regulators have enshrined central generation and largely continued to oppose local power generation.

Electricity, commercialized in 1880, is arguably the greatest invention of all time. But early developers faced a big problem, finding money for wires to transport electricity to users who didn't think they needed it. To manage the risk, developers asked city councils for five-year exclusive franchises.

Thousands of small electricity companies sprang up; by 1900, there were 130 in Chicago alone. Greedy aldermen sold votes to extend franchises. Samuel Insull conceived of (and got) an Illinois state-granted monopoly in perpetuity. State monopolies spread.

States established regulatory commissions to approve capital investments and set rates that assured utilities of fair returns on capital. Under rate-based regulation, investments in efficiency improvements increase the rate base, but all savings go to customers. This approach does not allow utilities to profit from increasing efficiency. The misalignment of interests eventually caused industry stagnation, but in the early years, utilities chased efficiency to compete with candles, oil lamps, muscle power and self-generation.

Banks cheerfully loaned money to monopoly-protected utilities, fuelling a race to grow and acquire other systems. Power entrepreneurs borrowed huge sums to gain control over vast areas of the country. In 1929, the bubble burst; demand for electricity sagged, and over-leveraged trusts could not pay debt service. Utility bankruptcies deepened the Great Depression. Congress' response – the Public Utility Holding Company Act (PUHCA) – prevented utility amalgamation and assigned federal watchdogs to oversee finances. PUHCA blocked profit growth via acquisition or financial engineering. Profit-seeking utilities had two options: to sell more power, and to invest more capital in the rate base.

Both strategies favoured central generation over local power. Utilities sponsored research in electric appliances, motors and other novel uses of electricity that increased sales and provided significant public benefits. But they also fought local generation with every available means.

Electricity distribution companies have an understandable bias against generation that bypasses their wires and cuts potential profits. Utility monopolies long made it 'job one' to preserve the monopoly. The electric industry sponsored 'ready kilowatt' campaigns to win industry love, and skilfully coached (and paid) governments at every level to block decentralized energy.

For eight decades, central generation was the optimal technology. The regulatory approach delivered nationwide electrification and real prices fell by 98%. Electrification not only improved standards of living, but also played a strong role in positive social change.

Then, beginning in the late 1960s problems arose. Central generation ceased to be optimal, but the industry ignored local power innovations. Which brings us back to stakeholder costs.

THE GOOD TIMES END

By 1960, as competition withered away, utilities began pursuing questionable strategies. With no way to recycle by-product heat, fuel efficiency never moved beyond 33%. Utilities and their regulators rushed to convert many coal-fired power plants to oil, just in time for the OPEC embargo in 1973. Many utilities committed to build massive central plants that required up to 10 years to construct, far beyond safe planning horizons. When rising prices induced conservation, electricity load growth flattened and left the industry with massive over-capacity.

Then came nuclear. The utility industry committed vast sums, underestimating complexity and safety concerns. Some nuclear plants were built near budget, but others broke the bank. Cost overruns of

300%–500% were common. Long Island Lighting spent 19 years and $5 billion building Shoreham, only to have New York Governor Cuomo close the plant before it generated any power.

Figure 1 shows the rising real prices of US electricity after 1968. From 1970 to 1984, real electricity prices rose by 65%. Prices are given in 1996 dollars as reported at www.eia.doe.gov.

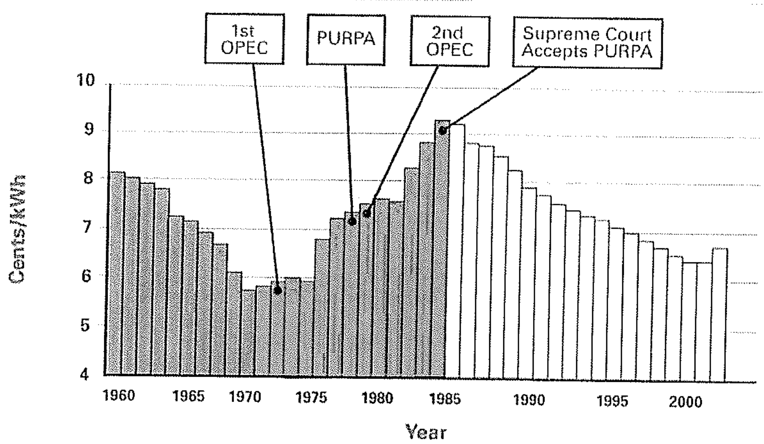


Figure 1. Real US electricity prices (1996 dollars)

Regulatory responses nearly got it right, flirting with local generation. The 1978 Public Utility Regulatory Policy Act (PURPA) sought to improve efficiency by exempting plants that recycled some heat from Federal Power Act regulations, and required utilities to buy power from these plants at avoided costs. Utilities fought PURPA to the Supreme Court, losing in 1984. But subsequent changes removed the pressure to build plants near users, and nascent DE was again driven back.

Next came Three Mile Island. State commissions, tired of nuclear cost overruns and rising prices, overturned the tacit regulatory compact. They challenged the prudence of utility investments in nuclear plants, claiming mismanagement. Historically friendly regulators ordered CEOs to remove billions of dollars from the rate base and reduce electricity prices. Utility shareholders took a bath.

The two changes did stop electricity price inflation: prices dropped to 1969 levels by 2000. But utility managements went into shock. They curtailed in-system investments, but still needed to put massive cash flow to work. Smarting from independent power producers' (IPPs') 'poaching' of their generation under PURPA, many utilities funded unregulated subsidiaries to poach generation in other territories. Never questioning the central generation mantra, utility subsidiaries began a disastrous race to build remote gas turbine plants, ignoring this strategy's vulnerability to rising gas prices. In the 13 months following May 2001, the 11 largest merchant power plant builders destroyed over $200 billion of market capitalization. Enron, NRG, and PSE&G and Mirant have since declared bankruptcy, while Dynegy, CMS and Mission struggle to pay creditors. Industry players that embraced gas-fired remote merchant plant development have seen their credit ratings lowered to junk status.

Major transmission failures did not start immediately. Spare transmission capacity, built in the days of compliant regulation, absorbed load growth until 1996, when a falling tree set off an 18-state blackout throughout the west. By then, load growth had made the non-growing transmission and distribution (T&D) system vulnerable to extreme weather (ice storms, tornadoes, hurricanes and drought induced hydro electricity shortages), human error and terrorists.

As costs and environmental concerns mounted, states began to experiment with partial deregulation, but never eased protection of wires, leaving utilities free to continue fighting DE by charging excessive back-up rates and denying access to customers. Commissions allowed generators to sell to retail customers, but then set postage stamp transmission rates, charging the same to move power across the street or across Texas. DE power, which only needs to move across the street, was left to pay the same transmission rates as power moving hundreds of miles through expensive transmission wires. Wholesale power prices give little recognition to the locational value of generation.

Environmental regulations also suppress decentralized generation. The 1976 Clean Air Act and subsequent amendments penalize efficiency. Almost all emission permits are granted based on fuel input, with no relationship to useful energy output. All new generation plants are required to install 'best available control technology', while existing plants retain 'grandfather' rights to emit at historic levels. These grandfather rights give economic immortality to old central stations and block innovation, and thus bear some responsibility for system failures.

The costs to all stakeholders from the central generation world view extend to other societal problems. The balance of payments suffers from needless fuel imports. The US demand for fossil fuel begets military adventures. Inefficient generation raises power costs, hurts industrial competitiveness and makes electricity generation the major source of greenhouse gas emissions, threatening entire ecosystems.

WHETHER TO SPEND OR SAVE OUR WAY OUT

There are two distinct paths to avoid more blackouts. Spend $50–100 billion on new and upgraded transmission lines; or save money by removing barriers to decentralized energy.

The first path will raise electricity rates by 10%–15% and will exacerbate other problems. The second path will cost taxpayers nothing and mitigate other problems. To follow the second path, governments must:

- allow any provider to sell back-up power
- enact standard and fair interconnection rules
- void laws that ban third parties from producing and selling power to their hosts
- give every power plant identical emission allowances per unit of useful energy
- recognize the locational value of generation
- most importantly, allow private wires to be built across public streets.

These changes would transform the $390 billion US heat and power business into a dynamic marketplace of competing technologies, and allow decentralized energy's competitive advantages to prevail. Utilities and IPPs will build new DE capacity to serve expected electricity load growth and reduce transmission congestion.

Ending central generation bias will upset vested interests and require a great deal of political effort, but the rewards for this leadership will be immense – lower power prices, reduced pollution, reduced greenhouse gas emissions, and a much less vulnerable national power system.

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