# Beyond the Blackout



By Vaclav Smil

Published 08/18/2003




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One of the first things I did after arriving in the U.S. from Europe in 1969 was to study the 1967 report of the Great Blackout that left 30 million people without electricity in November 1965. As I began to learn the particulars of the U.S. electricity system I was appalled by its splintered nature, by weak, or nonexistent interconnections between neighboring utilities, by its poor integration. Half a lifetime later there are more interconnections and much more electricity trading but the system remains incredibly splintered, astonishingly loosely regulated and clearly as prone to replicating, and surpassing, the Great Blackout of 1965: the Superblackout of 2003 affected twice as many people as did the 1965 episode, and it happened after explicit safeguards were put in place twice (after 1965, and once more after the 1977 event) to prevent precisely this kind of cascading outage.

American politicians blamed Canadians for the initial surge that set off the cascade; Canadian politicians were sure it was a power plant fire in the U.S. that started it all; Bill Richardson, Clinton's energy secretary, repeated to every TV camera that America has Third World electricity transmission; and the President assured us that he has been all along for doing something about this "old and antiquated" system. Investigators of the North American Electric Reliability Council (NERC) will soon detail the precise sequence of events (which began at 14:06 when a 345 kV Chamberlain-Harding line tripped and continued at 14:32 when another 345 kV line sagged and tripped) that led to the cascade.

We do not have to know it in order to appreciate why such events could have such an enormous impact. When looking for a perfect example of a technically complex and spatially extensive system it would be hard to find anything better than generation, transmission and distribution of electricity. Its successful operation requires a nearly flawless concatenation of these ingredients: adequate, and sufficiently redundant, generation capacity; reliable high-voltage transmission carrying the generated electricity throughout a particular service area; equally reliable high-voltage links between adjacent service regions that could be used to import or export electricity to meet changes in regional demand, to take advantage of staggered peak consumption in different time zones, and to optimize the loads of individual generating plants; and, finally, robust distribution lines to take low-voltage electricity from substations to individual users.

The Superblackout had nothing to do with distribution lines, although it is in this respect that North America's electricity system actually most resembles the Third World arrangements: rather than being carried mostly underground -- at a greater cost but with incomparably higher security and operational reliability as they are in downtowns and in most new suburbs -- hundreds of thousands of kilometers of the continent's distribution lines hang, 1880s-style, from wooden poles ready to be ripped up by storm winds, tornadoes, hurricanes, layers of ice and falling trees. These events can cause severe local or regional service disruption lasting many days or



even weeks but they do not put 60 million people in the dark.

Nor was the Superblackout a matter of insufficient capacity, of excessive, hot weather-spurred demand overloading the inadequate supply. Whenever there are disruptions in energy deliveries this comes first to a layman's mind, and even many instant experts see it often that way. Most notably, during the mid-1970s they were convinced that OPEC's oil price rises were reflecting the impending physical scarcity of rapidly disappearing oil supplies -- rather than being a simple extortion taking the advantage of our gluttony-induced rising oil demand. While there was a rare recent instance of real shortage of generating capacity in California, the northeastern part of America has more than adequate number of turbogenerators, and there is no white-knuckle 2 percent margin between the highest anticipated demand during hot summer days and the installed capability of thermal (coal-fired and nuclear) and hydro stations.

And so we are left with those Third World, old and antiquated transmission lines. Dismissing the first catchy phrase is easy: Third World transmission lines will typically carry every year less than 1-1.5 GWh/km per km while our annual average is more than 6 GWh/km. And the age is not an automatic cause for troubles. Again, a scientifically illiterate public and some instant experts think (an obvious byproduct of our use-and-throwaway society) that unless everything is brand new a system is inferior. But, to give just one glorious analogy, there are still plenty DC-3 (Dakotas) flying: of course, they have to be **maintained** properly and they do not have the **capacity** of Boeing 747 (and can carry only 30+ rather than 400+ people). So it is with too many older (30-50 years) transmission lines: when properly maintained they operate reliably but they have **limited capacity**. On the other hand, there are obviously thousands of kilometers of old lines that should have been rebuilt years ago.

And so we have a system that has been for many years imperiled by operating with dangerously narrow margins between the transmission capacity and demands put on it by increasing needs for large-scale inter-regional electricity transfers. Instead of making the grid more resilient by being more interconnected with more reliable, higher capacity lines, the U.S. has been marching backwards: the distance to which a given plant can expect to sell electricity during the conditions of peak demand, has been falling since 1984 (and will continue to fall during this decade) and the average trade area of a given generator is now only about 70 percent of the mean in the mid-1980s. The national mean of this trading distance is just 285 km, much lower than that even for the insular U.K. grid where it is about 960 km. On the other hand, just as well, because the overloading of existing limited-capacity transmission lines leads to their sagging and tripping.

One would also think that even kindergarten-type instructions for system engineers would include the great admonition to build a whole system where transmission capacities match (with a prudent reserve) the generation capabilities and to manage everything in a tightly integrated manner. Astonishingly, not in North America where since the 1970s new transmission lines have grown at less than half the rate of increasing electricity demand, and where utilities have been pushed to **separate** transmission and generation. This is how Michehl Gent, president of the NERC, puts it: "We no longer have transmission lines built to accommodate generation systems. . . When they separated, generators started building plants at convenient locations . . . without considering how transmission lines in that area would accommodate them." As incredible as this is, there is more: NERC's guidelines for managing the system that is splintered into parochial bits are voluntary, with no enforcement abilities. All of this adds up to a set-up where probabilities of major outage become unacceptably high.

New, enforceable rules can be put in place rapidly by an executive fiat.

Improving and increasing transmission capacities is another matter: Electric Power Research Institute (EPRI) estimates that fixing the deficit will need $ 50-100 billion. This reality alone makes the probability of another major blackout uncomfortably high. But, one might object, how can the country's leading electricity research outfit justify such an incredibly loose estimate? Unfortunately, the range is readily defensible and this fact points to an even more systemic problem that goes far beyond the Superblackout: EPRI's uncertain estimate reflects the magnitude of neglect of the continent's key infrastructures. Things are so bad that we cannot be sure how much it will take to fix them.

If you think about the chances of spending soon $100 billion to fix the grid think about this: the replacement value of concrete installed in America's crumbling highways, bridges, runways, pipes, canals and buildings is on the order of $6 trillion (or some two-thirds of annual GDP). As most of it was emplaced between the mid-1950s and the mid-1980s it is increasingly due for repairs, and the above estimate does not include the cost of disposal of the removed concrete as there is no practical way to recycle that mixture of hydrated cement, sands, gravel and metal. Clearly, fixing infrastructures is more daunting, and lot less glamorous, then putting them in place. We are yet to begin this challenging task.

*Vaclav Smil's latest book, Energy at the Crossroads, will be published by the MIT Press this fall.*

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