Chapter 15
Overview of the Electric Grid: Herding Lightning

At a U.S. Senate Hearing, Senator Ron Wyden of Oregon asked energy conservation advocate Amory Lovins if the Administration's FY2007 budget request of $942-million for the Advanced Energy Initiative, $1.18-billion for energy efficiency and renewables, and about ten times that amount for various nuclear energy programs would do anything to deal with what President Bush called our "national oil addiction."

Lovins replied "I'm sorry to say no," and pointed out these proposals would not reduce oil imports because the programs were for technology that would generate electricity, which has nothing to do with oil. "This confusion between oil and electricity, conflating them both into 'energy,' bemuses energy experts the world over who assume responsible U.S. officials must understand these fundamentals; yet such jumbled formulations persist" (Senate 109–412 2006).

Cars, trucks, trains, and ships all use oil, a liquid fuel. Not electricity.

Electricity does not solve an imminent transportation oil crisis because the nation cannot, in the blink of an eye or in a few years or probably decades, convert or build trucks and locomotives to operate with power from millions of miles of overhead wires or many millions of tons of batteries.

But if the national plan is to transition, over many decades, to operate transportation with electricity, then we have to start with a clear understanding of the present U.S. electric grid, and how it has evolved.

The grid began a century ago with utilities that did everything in their region. In the beginning, they were like islands. The utilities owned the power plants and the transmission system delivering electricity over the web of wires, controlling it like a master chef at a stove turning the flame up and down to exactly match supply with customer demand. When the utility screwed up, the results were worse than a charred steak—a blackout could occur.

Flash forward to today. No utility is an island. They are all interconnected. The U.S. and Canadian grid is often called the world's largest machine, valued at more than $1 trillion with over 6000 power plants, 200,000 miles of high-voltage lines, 390,000 thousand miles of transmission lines, 55,000 substations, 6 million miles of distribution lines, all connected to communication, computer, and control systems.

A.J. Friedemann, *When Trucks Stop Running*,
Energy Analysis, DOI 10.1007/978-3-319-26375-5_15

Over the decades, deregulation added further complexity to the grid. 65 % of utilities that were “single chefs” responsible for electricity end to end, from power plant to light switch, were broken up into thousands of entities. They became specialists—services include electricity buyers and sellers, power plants owners, resource planners and schedulers, distribution providers, and reliability authorities.

Compounding this complexity, the electric system has many federal, regional, and local governing agencies. These entities work within the three grids of the continental U.S.: The 11-state Western (WECC), Texas (ERCOT) its own island of power, and the 36-state Eastern interconnection (EC). Within these grids are other regions, and over 110 balancing authority areas. The chefs who run them may have the most important job to keep the grid up: Demand by all of us who use electricity to toast our waffles, cool our homes, and make aluminum must be exactly balanced by the supply of electricity being produced and coming to us over that grid. Supply and demand is balanced by operators who constantly interact with each other, calling up power plants to increase or decrease power, and wheeling power to hither and yon across the grid.

Buyers and sellers move electricity across vast regions in ways the system was never designed for, and many private utilities seek profits by cutting back on maintaining transmission, research and development, and staff.

This cost cutting has led to the majority of equipment being 50–70 years old, which makes it three to ten times more likely to fail, and more vulnerable to natural disasters, cyberattack, and terrorists (Willis et al. 2013; NRC 2012). The more maintenance and replacement are deferred, the more times the lights will go out.

The American Society of Civil Engineers gives U.S. energy infrastructure a grade of D+ because “America relies on an aging electrical grid…. Ongoing permitting issues, weather events, and limited maintenance have contributed to an increasing number of failures and power interruptions, from 76 in 2007 to 307 in 2011…. Congestion at key points in the electric transmission grid has been rising over the last five years, which raises concerns with distribution, reliability and cost of service…. This congestion can lead to system-wide failures and unplanned outages” (ASCE 2013).

The grid is not just an inanimate flow of electrons through wires, transformers and so on. Batteries of highly skilled workers make the grid go. Half are eligible to retire within the next 10 years. Many utilities see a lack of skilled employees as their biggest problem, with few electrical engineers being trained to replace them since pay is so much higher outside of the utility field. In addition, few power engineering programs are offered at universities (NRC 2012).

Three kinds of power keep the U.S. grid in balance:

1. Baseload power, mainly from coal (40 %) and nuclear (20 %) which can always be counted on to generate the minimum level of demand around the clock.
2. Intermediate “load following,” wherein natural gas plants or hydropower kick in at daybreak when factories and coffee pots rev up, then shut down at night.
3. Natural gas “peaker” plants and hydropower, with the unique and indispensable ability to go from standby to full-blast almost instantly when there is high

demand, such as on hot days for air-conditioning which uses enormous amounts of electricity. Peakers also are essential for balancing the grid because of the intermittent nature of wind and solar. More wind and solar would not be possible without peakers to quickly balance the grid.

The twenty-first century grid that lights our life could never have been imagined 150 years ago when the first isolated DC power systems were built in the 1880s. It is as delicate as it is vast. Power production generators throb in unison, pushing power out at nearly the speed of light across transmission lines, like monks chanting "Ohm." Disturbances self-correct as magnetic forces and the rotational inertia of generators naturally revert back to the right frequency and voltage—a good thing, since variations just a few percent off of 60 Hz can damage equipment, cause a local power outage, and even a cascading blackout if transmission lines and other equipment are overloaded (Lerner 2014). In 2003, over 55 million people were affected by a blackout in the Northeast.

Planning for reliability starts when power plants are scheduled for the next day based on weather forecasts and historic load patterns. There must be the right mix of baseload, intermediate, peaking, and other electrical services scheduled. When cities wake up, the show begins as machines, devices, and lights are turned on.

As demand surges, sellers send power to distant buyers. Operators can't control where electricity flows—it takes the path of least resistance across all available paths, so operators scramble to keep the grid balanced, making corrections as soon as imbalances occur.

With so many chefs, it is truly remarkable that what is perhaps the largest and most complex machine ever created is up 99.8 % of the time. If electricity were used to run our transportation systems, the electric grid would be severely challenged to provide enough power, especially as destabilizing intermittent power provides more and more of generation, which will be explored in the next chapter.

References

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