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Science and technology

Babbage

RELIABILITY OF THE GRID

Difference Engine: Disaster waiting to happen

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LAST weekend's vigilance against potential terrorist attacks was an impressive demonstration of America's resolve to prevent events of September 11th 2001 from ever happening again. From your correspondent's hillside perch above Santa Monica Bay, he watched National Guard F-16 jets make repeated sweeps across the ocean by Los Angeles International Airport and then on to the huge port complex of Long Beach and San Pedro, while a Navy P-3 Orion maritime-surveillance aircraft circled overhead. The cacophony was deafening but reassuring. Angelinos slept easier that night.

Yet, further down the coast, 6m citizens of southern California and south-west Arizona, along with their cousins across the Mexican border, were just recovering from a man-made disaster that had plunged their sweltering world into darkness—shutting down schools, hospitals, offices, factories, shops and restaurants, as lighting, air-conditioning and other essential equipment ceased to function.

Beaches in San Diego had to be closed to the public because raw sewage had seeped into the sea. Passengers on trains stuck between stations and trapped in lifts had to be rescued by the police. Flights from San Diego International Airport were cancelled because of the lack of runway lighting.

With traffic lights out of action and petrol stations unable to pump, motorists abandoned their vehicles and added to the gridlock that ruled the roads. By great good fortune, no-one died or was seriously injured. But normal life, for those so affected, ground to a miserable and unnerving halt.

The difference between the two events could not have been more stark. One was all about preparedness and professionalism. The other was a forceful reminder of the chaos wrought by personal negligence and institutional neglect. “We don’t need no lousy terrorists to cause mayhem,” San Diegans must have reflected afterwards. “We can manage just fine by ourselves.”

The power outage that swept across a large swathe of the American south-west on September 8th was the region’s worst cascading blackout in 15 years. It started at the North Gila substation near Yuma, Arizona, where a utility employee “was doing some work” on faulty equipment.

Something happened (still under investigation) to cause the substation to shut down, disconnecting a 500kV transmission line connected to it and disrupting the electricity supply to Yuma’s 90,000 residents. The immediate power shortage at Yuma caused the current—which normally flows along the grid’s key Southwest Power Link from Arizona to California—suddenly to reverse its direction.

The result was a violent fluctuation in line voltage that fed back through the grid to trip switches at substations throughout the San Diego area. Altogether, some 15 power stations in the region shut down automatically to protect themselves from voltage swings—the biggest being the 2,200MW San Onofre nuclear power plant up the coast near San Clemente.

With the San Onofre plant disconnected and the umbilical cord from Arizona effectively severed, the delicately balanced grid serving San Diego and its adjacent counties quickly became unstable. Such problems would normally be resolved by ratcheting up the output of surrounding power stations. But with so little base-load capacity in the area, standby plants for meeting peak demand could not be spun up fast enough to stabilise the voltage.

The overloaded grid promptly crashed, causing blackouts to spread across the region and into Mexico. The lights did not come back on until the following morning. The wind was blowing at only 8mph and the sky was partially overcast. So, California’s lauded sources of renewable energy were of little help.

If anything, they were part of the problem. Critics point out, with some justification, that California’s energy strategy of focusing on conservation and expanding intermittent sources of renewable energy—while ignoring the urgent need for more base-load generating capacity close to big cities—was the primary cause of the grid failure. The wider issue is that the original voltage spike which triggered the monster outage should have been isolated at the Yuma substation in Arizona.

The two official bodies responsible for overseeing the distribution and reliability of bulk power in the United States—the Federal Energy Regulatory Commission (FERC) and the North American Electric Reliability Corporation (NERC)—have launched an inquiry to learn why that did not happen. Their report will no doubt apportion blame and recommend changes in maintenance procedures. But few expect it to address the underlying problem. Both FERC and NERC are only too aware of the structural reasons why the American grid has become so fragile.

They are equally aware of how intractable to solution those reasons are. As elsewhere, the electrical-power industry in America has changed over recent decades from a collection of heavily regulated regional monopolies to a complex, competitive, national, free-market business. In the process, electricity has become a commodity, with futures and contracts traded by participants just like any other commodity business. Independent power providers and transmission companies construct their own facilities, often paid for with bonds backed by future revenue streams.

Retailers sign up customers, buy the electricity from wholesalers around the country, and bill users for it. Managing supply and demand, once the prerogative of the utilities' planners, has become a process shaped largely by an energy company's appetite for risk. Meanwhile, independent system operators who schedule the dispatches of electricity have become, effectively, asset managers—using market-clearing prices to equilibrate between bids by suppliers and those from retailers. By and large, such changes have made energy markets more efficient. For consumers, the competition created by deregulation has kept a lid on electricity prices.

But it has had downsides, too. One of the biggest is the way it has removed what little spare capacity the grid once had. In the power industry's new competitive environment, transmission companies operate their lines at near full capacity, leaving little room for those threatening fluctuations in voltage caused by accidental outages. Compounding matters further is the way long-distance transmission lines connecting utilities around the country are being used differently these days.

Before deregulation, such links were employed largely for emergencies—for when, say, a utility found its voltage dipping precipitously and a brownout imminent. Today, long-haul power lines are frequently made to handle more power than they were designed to, as wholesalers sell their electricity over longer and longer distances.

The juice that comes out of a plug in clean-energy California can easily have come from a dirty coal-fired plant in Wyoming or West Virginia. As a result, the grid now suffers far greater fluctuations in electricity flow than ever before. The continual cycling of power plants up and down to meet demand from elsewhere in the country causes generating and transmission parts to heat up and cool down repeatedly.

No surprise that they then wear out faster. Meanwhile, the amount of money the American power industry spends on maintenance has declined steadily, by 1% a year since 1992. With the grid's most critical components—the transformers at substations—now typically 40 years old, there are serious consequences for the stability and reliability of the grid as a whole. Another downside of deregulation has been the decline in investment.

As the independent power providers, the electricity retailers and the utilities have no responsibility for the grid's main links, they have little incentive to maintain them properly. And as long as it is possible to purchase electricity elsewhere, there is little further incentive—as in the case of San Diego—to add more capacity locally. More and more blackouts sweeping the country are therefore inevitable.

Will the so-called “smart grid” improve matters? It could do the opposite. All the smart grid does is add a communications layer to the local electricity-distribution network—so consumers can see at a glance how much electricity they are using at any time of the day, and how much it is costing them.

Alerts sent by the utility at peak periods will allow customers to cut back their consumption and save money—or have it cut back for them to reap extra rewards. The real aim, of course, is to save the utility from having to invest in additional capacity. What is rarely mentioned in all the proselytising about the smart grid is that it adds a vast layer of hackable points to the network—some 440m by 2015, according to Lockheed Martin’s Energy and Cyber Services.

Every smart meter in the home will be a hackable device. The same goes for all the routers at substations. As the saying goes, if you can communicate with it, you can hack it. Today, you can cut off the power to someone’s home by shinning up the nearest electricity pole and throwing a switch at the top.

Once smart meters become widespread, you will be able to do that remotely, from the far side of the world.

But evil-doers from afar might not stop at that. Instead of switching off the power, they could run the voltage up and down to wreck sensitive electronic equipment, such as computers and television sets. And they could do that not just on single homes, but on whole communities and even to routers in substations—in an attempt to take transformers offline, if not actually fry them.

As we saw last week, the failure of just one substation in Yuma was enough to bring a whole chunk of the American south-west to its knees. Unless the grid is made more robust and secure, the threat to the country—from terrorist or technician—can only become more severe.