issues & events

US electricity grid still vulnerable to electromagnetic pulses

Experts warn lawmakers that an intense solar storm or an attack by a single nuclear weapon could knock out power in an entire region for months.

In April 1999 Representative Roscoe Bartlett (R-MD) was part of a House delegation that traveled to Vienna to meet with counterparts from the Russian Duma in an attempt to defuse US–Russia tensions over the North Atlantic Treaty Organization's military actions in strife-torn former Yugoslavia. Bartlett recounted to a reporter how one of the Russians—Vladimir Lukin, who was previously Russian ambassador to the US—angrily declared that if Russia wanted to harm the US without incurring nuclear retaliation, it would simply launch a single nuclear-tipped missile from a submarine and detonate the warhead high in the atmosphere over the American continent. Gamma rays from the explosion would interact with the atmosphere to produce pulses of electromagnetic energy that would wipe out the electricity-generating and transmission system across a huge portion of the continent. The US would be rendered helpless for six months or more, Lukin boasted.

Later Bartlett slipped into the 2001 Department of Defense authorization bill a provision creating a commission to study the threat posed by an electromagnetic pulse (EMP) attack. In its 2004 report, that commission warned that a single nuclear device detonated at an altitude of 40 to 400 kilometers would create a "radio-frequency wave of unique, spatially varying intensity that covers everything within line-of-sight of the explosion's center point." The results, said the report, could be catastrophic: "A single EMP attack may well encompass and degrade at least 70% of the Nation's electrical service, all in one instant."

Such a deliberate attack seems farfetched, but EMPs capable of taking down parts of the grid are also caused by geomagnetic storms, in which rapidly varying ionospheric currents can produce direct-current flows known as geomagnetically induced currents. One such storm, in March 1989, blacked out the entire province of Quebec for nine hours. The failure was caused when geomagnetically induced currents knocked out components in northern Quebec. Solar storms of far greater intensity have occurred, causing auroral effects at far lower latitudes. An 1859 event known as the Carrington flare caused US telegraph lines to glow and spark and created brilliant auroras visible even in tropical locations.

According to a study presented at a 2008 National Academies workshop on space storms and the grid, historically large geomagnetic storms could create "power grid blackouts and transformer damage of unprecedented proportions" inflicting $1 trillion–$2 trillion in damage and requiring 4–10 years for a full recovery. By comparison, the damage caused to the Gulf Coast by Hurricane Katrina was estimated at up to $300 billion. The study, performed by Metatech Corp in Goleta, California, said that severe storms with "the potential for long-duration catastrophic impacts to the power grid" in the US occur about once every 30 years.

"That's a serious powerlines effect!"

A third, more localized EMP threat could be posed by terrorists with portable electromagnetic weapons. A coordinated attack using such devices at several locations could destabilize the grid, according to witnesses at two House committee hearings held in July. Plans for such devices are available on the internet, and the US Navy has demonstrated that they can be built with parts costing $500.

Restoration could take years

Particularly vulnerable to an EMP are the extra-high-voltage transformers that step up and step down bulk power for long-distance transmission. According to Paul De Martini, vice president of advanced technology at Southern California Edison, many of those house-sized transformers are essentially custom-made, and few spares exist. One such transformer was irreparably damaged in the 1989 Quebec blackout. No domestic manufacturers make those transformers, and replacing as many as could be destroyed in a major EMP event could take two to three years, De Martini said in recent congressional testimony. One estimate put the number of high-value, extra-high-voltage transformers requiring shielding from EMPs at approximately 5000.

In an interview, Bartlett warns that the Obama administration's planned major upgrade of the US electricity transmission system will exacerbate the grid's vulnerability. The Department of Energy's $4.5 billion "smart grid" program is expected to accommodate major growth in wind and solar electricity generation and enable real-time management of electricity flows by producers and consumers alike. But the smart grid will employ various digital sensors and control devices that could become additional targets for hackers and saboteurs. DOE is supporting R&D to enhance the smart grid's cybersecu-

rity and is requiring that components developed with DOE funding include defenses against cyberattacks. But the agency currently has no such activities to address the EMP threat, Patricia Hoffman, acting director of DOE's office of electricity delivery and energy reliability, told lawmakers.

Bartlett says he scoffs when individuals suggest that he keep his EMP concerns private so as not to give terrorists any ideas. "I can assure you that every one of our enemies knows all about EMP." He points to the EMP commission finding that the former Soviet Union developed nuclear weapons that were optimized to produce an EMP and that Soviet plans to wage war against the US included an initial EMP assault to paralyze the nation.

An attack without fingerprints

An EMP device is "the ultimate asymmetrical weapon," Bartlett says. An adversary would need only to build a crude nuclear bomb, load it onto a Scud missile and launcher that could be purchased for $100 000 or so, and send it aboard a freighter to a location off the US coast. After the launch, the ship could be sunk, removing any evidence of its origin. In Bartlett's scenario, the US, even as it is crippled by the EMP, would have no target against which to retaliate.

William Graham, who chaired the EMP commission, noted at one hearing how EMPs and their effects were observed during the US and Soviet atmospheric nuclear test programs in 1962. One test warhead, code-named Starfish, was detonated at an altitude of 400 kilometers above Johnston Island in the South Pacific; it caused street-lighting systems to fail, tripped circuit breakers, triggered burglar alarms, and damaged a telecommunications relay facility in the Hawaiian Islands, 1400 kilometers away. (See PHYSICS TODAY, August 2008, page 18.)

The vulnerability to EMPs was raised by the Congressional Commission on the Strategic Posture of the United States, formed to recommend changes to US nuclear weapons policy. In a report issued earlier this year, the commission said that the US "has done little to reduce its vulnerability to attack with electromagnetic pulse weapons" and recommended that smart grid efforts "take account of the risk." Commission member John Foster, a former director of Lawrence Livermore National Laboratory, also served on the EMP panel.

Although Bartlett has for years been a lone congressional voice on the danger of EMPs, he has gained an influential ally from across the aisle: Homeland Security Committee chairman Bennie Thompson (D-MS). Both Thompson and Yvette Clarke (D-NY), chairwoman of the subcommittee that has jurisdiction over cybersecurity, asserted that electric power companies were failing to take the EMP threat seriously. Clarke went further, charging that many utility companies have been "trying to avoid compliance with their own inadequate standards" by choosing not to identify what assets they deem critical in order to avoid having to protect them.

Utility company officials maintain that they are awaiting guidance from the government on the extent and nature of the EMP threat before they take action. Steven Naumann, a vice president of Exelon Corp, complained to lawmakers that the private sector isn't privy to all intelligence that could help in determining the urgency of the perceived threat. Naumann said the industry has to know the maximum anticipated level of EMPs in order to design shielding systems to protect the equipment.

An Edison Electric Institute spokesman said that there would be little point in ensuring the electric grid will survive an EMP attack if the nation's transportation, information systems, and other infrastructure were knocked out. That's in contrast to the EMP commission report statement that protection of the electric system is paramount because all other critical infrastructure requires electricity to function.

Advance warning would help

As for solar storms, the EEI spokesman noted that utility companies can take mitigating actions to protect grid components if given enough warning time. Metatech developed and operates a geomagnetic-storm forecasting service for power-grid operators in England and Wales. Using satellite data on solar wind, the service gives out a warning approximately 45 minutes ahead of a solar storm so the operators can take protective action, the company said in written testimony. Operators could, for example, decide to remove certain extra-high-voltage transformers from operation to reduce their exposure to EMPs, or reduce or shed loads in portions of the grid to limit damage. But Metatech cautioned that installing such a forecasting system for the US grid would be complicated by the system of multiple grid operators, who would need to agree in advance on their responses to an EMP event.

Thompson, along with 30 cosponsors, has introduced legislation (HR 2195) that would order the Federal Energy Regulatory Commission to set requirements for the protection of the grid against cyber and physical threats, including EMPs. A companion bill has been introduced by Senator Joe Lieberman (I-CT). The legislation has broad support, including from electric utilities.

Joseph McClelland, director of FERC's electric reliability office, told the Homeland Security committee that FERC would allow utilities to recover the costs they incur in complying with grid-protection mandates that the agency issues. McClelland, who spent 20 years in the utility industry, said electric producers know about the danger of EMPs but are unlikely to take mitigating action against such a low-probability occurrence unless regulators make them do so.

Incorporating EMP shielding into new smart-grid components could add anywhere from 2% to 10% to their cost, based on the Pentagon's experience with EMP shielding of military equipment, Bartlett says. Metatech recommends that passive devices or circuit modifications be installed to block or reduce the flow of geomagnetically induced currents. Installing resistors on the neutral-to-ground connections of transformers could reduce such currents by 60%, the company said, without substantially reducing the grid's efficiency. A preliminary estimate by the EMP commission put the cost of protecting the inventory of US and Canadian high-value transformers in that fashion at around $150 million. But it cautioned that its analysis was based on simple devices at a conceptual stage.

Curtis Birnbach, president of Advanced Fusion Systems LLC in New Rochelle, New York, said his company had developed switches that will detect the pulse of an EMP and react in less than one-billionth of a second to safely conduct it to ground. He estimated that his company could shield a typical high-voltage substation for $1.5 million, or roughly 10% of the substation's cost. But whatever the expense of protecting the grid from a severe geomagnetic storm, it is likely to be far less costly than the economic impacts from a widespread and lengthy blackout. DOE estimated the economic impact from the August 2003 blackout of the Midwest and Northeast, which was caused by trees and not EMPs, at $10 billion.

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