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Preparing for the next big solar storm

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The probability of a solar storm striking Earth in the next decade with enough force to do serious damage to electricity networks could be as high as 12 percent, according to solar scientists.

One such storm erupted from the surface of the sun two years ago, on July 23, 2012. If it had been directed at this planet, it would have produced the worst geomagnetic storm in more than four centuries and caused extensive power problems.

Fortunately, on this occasion, the eruption pointed away from Earth and the storm blasted safely out into space.

But if it had occurred just a week earlier, when the site was pointed directly at our planet, billions of tons of highly charged particles would have raced toward Earth's magnetic field at a speed of 2,500 km per second.

The result would have been a spectacular display of the northern lights (aurora borealis) and southern lights (aurora australis) visible as far as the equator, turning the night sky as bright as daytime.

But it could also have fried the world's electricity grids and left hundreds of millions of customers without power for months or even years.

In the event of an eruption directed at Earth, politicians and power grid operators would have just a few hours from the first signs until the full fury of the storm hit to protect the electrical systems on which modern life depends.

"The July 2012 solar storm was a shot across the bows for policymakers and space weather professionals," U.S. solar researchers warned in the journal Space Weather last October.

"Our advanced technological society was very fortunate, indeed, that the solar storm did not occur just a week or so earlier. Had the storm occurred in mid-July the Earth would have been directly targeted ... and an unprecedentedly large space weather event would have resulted."

"There is a legitimate question of whether our society would still be picking up the pieces," they concluded.

Scientists and power grid operators remain divided over how much damage the power grid would suffer in a severe solar storm aimed directly at Earth.

A moderately severe geomagnetic storm aimed at the United States could cut power to 130 million people and damage more than 350 high-voltage transformers, which would take months to replace, according to a report published by the U.S. National Academy of Sciences in 2008.

A really severe storm could inflict damage and disruption estimated at between $1 trillion and $2 trillion, 20 times the cost of Hurricane Katrina, with a full recovery time between four and 10 years, the academy wrote ("Severe Space Weather Events: Understanding Societal and Economic Impacts," 2008).

"The loss of electricity would ripple across the social infrastructure with water distribution affected within several hours; perishable foods and medications lost in 12-24 hours; loss of heating/air conditioning, sewage disposal, phone service, fuel re-supply and so on," according to a study funded by the U.S. government.

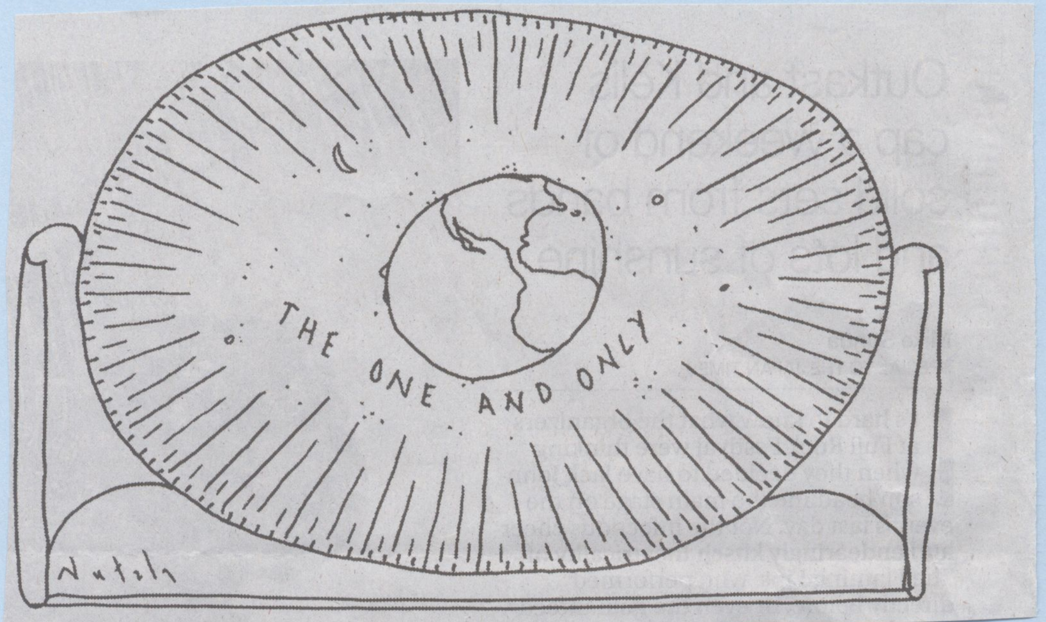
Older electrical transformers would be at particular risk of being damaged by the enormous electrical currents induced in the power grid by a severe storm. Transformers cannot just be ordered from a store. Spare units are in limited supply. Ordinarily it takes up to 15 months to order, manufacture, install and test a high-voltage transformer — even longer for some specialized equipment. "The need to suddenly replace a large number of them has not been previously contemplated," the U.S. government's Oak Ridge National Laboratory warned in 2010.

The problem is not just manufacturing. High-voltage transformers are exceptionally large and heavy, so they have to move slowly by ship, road and rail, and cannot be air freighted. Moving one even a few kilometers requires weeks of planning.

"It may take one week to move a 250,000-volt transformer a short distance in major metropolitan areas," Oak Ridge explained. "Even the distance of a few miles may take an entire weekend, as a number of traffic lights have to be removed and reinstated as the load is moved at snail's pace in special trailers and the route taken has to be fully surveyed for load-bearing capability by civil engineers."

Grid operators are more sanguine about the risks. Severe geomagnetic storms are more likely to cause blackouts and short-term power loss, rather than permanent damage, according to a report prepared by the North American Electric Reliability Corp. in 2012.

NERC thinks a severe storm would heat up a fully loaded transformer to around 120 degrees Celsius for roughly four minutes, well below the 200-degree design threshold used for modern equipment. A really severe storm could push temperatures over 200 degrees for 14 minutes, potentially causing failures,



but is unprecedented in modern times, according to NERC.

Nonetheless, the industry has established a special working group on mitigating the effects. And in May 2013, the Federal Energy Regulatory Commission formally directed NERC to develop reliability standards to help protect the U.S. grid from solar storms.

NERC characterizes severe geomagnetic storms as "high-impact, low-frequency" (HILF) risks. High-impact, low-frequency risks are particularly hard to manage because policymakers must decide how much money to spend on reducing a risk that would be catastrophic but seems remote.

However, recent research suggests the probability of a severe storm hitting Earth may be much higher than NERC assumed.

The worst solar storm on record occurred on Sept. 1, 1859, and was observed by an amateur astronomer in England called Richard Carrington, after whom the Carrington Event is named.

A large solar flare erupted from the surface of the Sun lasting for around five minutes. At the same time, a huge mass of highly charged particles, known as a coronal mass ejection (CME), was flung toward Earth at speeds up to 2,000 km per second, according to reconstructions by modern solar scientists.

The first particles reached Earth within an hour and the storm peaked around 17 hours and 40 minutes after the flare was observed.

The Carrington Event occurred in a largely pre-electrical age, so the impact was limited. But it was strong enough to damage severely the new telegraph systems installed in North America and Europe.

The next big solar storm, reported in May 1921, brought the U.S. telegraph service to a halt between the East Coast and the Mississippi River, blowing fuses and burning some operators.

In March 1989, a severe geomagnetic storm blacked out Quebec's power grid in less than two minutes — the worst impact to date.

In October and November 2003, the so-called Halloween storms caused isolated transformer failures in North America and Europe.

Measuring the severity of a storm is tricky because it depends on so many factors, including the size of the flare, the scale of coronal mass ejection, the speed at which it travels from the sun to Earth, magnetic flux, time of day, and location of the direct hit.

But one common summary statistic used by solar researchers is called "disturbance-storm time," or Dst for short.

The Dst index measures how hard Earth's magnetic field shakes when a storm hits, according to NASA. Dst is measured in nano-Teslas (nT). The more negative Dst becomes, the worse the storm.

The Carrington Event in 1859 is estimated to have had a Dst index of around -850 nT. The Quebec storm in 1989 clocked in at -589 nT and the 1921 storm was probably on a similar scale.

What frightened the solar scientists was that the July 2012 storm would have had a Dst index of up to -1,200 nT if it had struck Earth, making it much worse than the Carrington Event.

Scientists are able to analyze the July 2012 storm in detail because although it was angled away from Earth it made a direct hit on a solar observation satellite, STEREO-A, which is specially hardened to withstand extreme magnetic disturbances.

But had it hit Earth, it would have done severe damage to power grids and satellite communications.

Severe solar storms occur much more often than previously thought.

Like many natural phenomena, the frequency with which solar storms take place scales as an inverse power of the severity of the event. But the sheer num-

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ber of large storms over the last 150 years suggests the Carrington Event is unlikely to be an isolated occurrence.

Calculations by solar scientist Pete Riley, at Predictive Science Inc, suggest the probability of a solar storm of at least the power of the Carrington Event hitting Earth in the next 10 years is around 12 percent ("On the probability of occurrence of extreme space weather events," February 2012).

While not high, a 12 percent probability hardly qualifies as a "low-frequency" or remote-probability event.

So it is essential that the power industry and policymakers better understand how it would impact vulnerable systems (including the grid, global positioning system, radio and television communications, satellites and aircraft), harden them where possible, and plan how to cope with the aftermath of a big storm.

Once a large flare is detected, the industry and policymakers would have just an hour or so to put the grid and other systems into the safest possible operating mode before the storm arrives.

Before the next major storm arrives, it is essential to understand which transformers and other equipment are most at risk. Policymakers must consider whether to replace, redesign or otherwise harden the most at-risk equipment to withstand the impact.

It is also essential to identify how the grid (and other systems) could be rendered as safe as possible before the storm strikes.

Readying the grid could involve turning the power to customers down or off to reduce the loading on critical transformers and make them less vulnerable to overheating.

If power and communications systems are likely to be disrupted, businesses, households and government agencies will need to be informed quickly. And once the storm has passed, grid operators and policymakers must have a plan for damage repairs.

Grid managers already plan how to re-energize the grid after large-scale blackouts such as the one that hit the northeast U.S. and neighboring parts of Canada in August 2003.

The process is known as a "black start" and involves a careful sequence of steps to restart power plants, re-energize power lines and transformers, and gradually restore supplies.

But a severe solar storm might also cause more permanent damage, so the industry needs to supplement its black start procedure with a plan for handling multiple transformer outages.

Between 1996 and 2010, the SOHO satellite recorded almost 15,000 coronal mass ejections. It is only a matter of time before one of them is aimed at Earth and is of the same magnitude as Carrington, or worse. Given the frequency of large solar storms, most people reading this article will witness at least one.

And given society's increasing dependence on electricity and electromagnetic communications, storms could do much more damage in future, just one way in which new vulnerabilities are emerging in high-tech economies.

The biggest threat is probably in emerging markets, especially middle-income countries, where the combination of widespread electrification and electronic communications coupled with outdated and overloaded equipment makes them especially vulnerable.

But even in the most advanced economies, a severe solar storm could leave homes and businesses without power for months. Proper risk management and preparation are therefore essential.

We cannot stop a big solar storm arriving, but we can prepare and try to avoid its worst effects.

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