Vulnerability to Space Weather

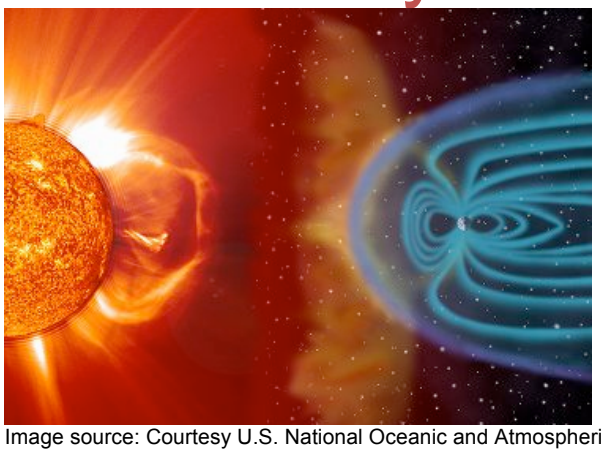

Image source: Courtesy U.S. National Oceanic and Atmospheric Administration (NOAA).

Solar super storms

According to NASA, the US National Oceanic and Atmospheric Administration (NOAA), the Sun may be entering a particularly vicious solar maximum in 2013, similar to that in which the Solar Super Storm of 1859 (*the most powerful solar storm ever recorded*) occurred (Moskowitz 2011, NASA 2010, US NRC 2008).

Solar storms can greatly compromise the integrity of electrical grids and damage electrical equipment and satellites.

The effects that the electromagnetic pulses (EMP) of a solar super storm would have on Smart Meters, smart grids and smart technologies have yet to be fully assessed. Such storms are already a major threat to less vulnerable grid systems (Birnbach 2011).

The US and UK are now planning to undertake “controlled” power cuts to their national electricity supplies to protect them against potential damage from large solar storms that might otherwise take months or even years to repair (Connor 2011).

1859 & likelihood of similar events

During the 1859 event, the most powerful solar storm ever recorded, caused the telegraph systems in North America and Europe to short out creating electric shocks and numerous fires (Odenwald 2000). Nowadays the effects would be far more damaging and widespread due to the increased use of electricity and more complex technology that is more easily damaged.

Marusek (2007) claims that such a storm could cause long-term blackouts in the USA, Canada, Europe, China, Central Asia, Russia, Argentina, Chile and New Zealand.

According to Dr Richard Fischer (Hough 2010), director of NASA's Heliophysics Division, the next solar storm of such a magnitude hitting Earth "*will disrupt communication devices such as satellites [as used for some smart grid communications – present author's comment] and car navigations, air travel, the banking system, our computers, everything that is electronic. It will cause major problems for the world.*"

On 7th June 2011 the largest ever observed coronal mass ejection from the Sun took place (Mosher 2011).

According to Antti Pulkkinen, head of NASA's "Solar Shield" satellite-based detection system, such events could cause a "*major space weather event*" if they were orientated towards the Earth (Behr & ClimateWire 2011).

It is predicted by some scientists that the Sun's 11-year cycle will now hit its maximum in late 2013 or early 2014. Phillip Chamberlin of NASA's Solar Dynamics Observatory said that there could be very energetic solar storms "*every couple of months instead of years*," at that time (Mosher 2011). It appears imperative to have smart grids protected against such events.

Such an event would cause individuals to be without electricity for hours or days. In the worse case scenario, large areas of the Earth would be without electricity for longer periods, possibly several months. Countries with "*fragile*" grid infrastructures are likely to be affected most.

It is predicted that upcoming solar flares could greatly endanger national security and take down key services such as electricity grids, electronics and communications for prolonged periods.

It is predicted that the next solar super storm could occur in 2012-2014. The 1859 super solar storm took place during a solar cycle of about the same size that NASA is predicting for 2013 (NASA 2009).

The present design of many high-tech devices (including Smart Meters) makes them more vulnerable to the effects of space weather than the units and technologies they replace. Transformer designs could also be improved (Birnbach 2011, EMPrimus 2011).

Solar storm of 1989

Generator step-up transformer damaged by March 1989 solar storm.
Images: Kappenman (2011). Images originally provided courtesy of Public Service Electric and Gas and Peter Balma.

The geomagnetically induced currents (GICs) that the solar storm of 1989 created caused the overloading of circuits, tripping of breakers, and (in severe cases) even melted the windings on heavy-duty transformers (NASA 2010). Transformers were damaged in the USA, Canada and the UK. Satellites were also damaged – *this latter fact is mentioned as some smart grids use satellites for communication which might get damaged in future solar storms.*

The March 1989 event was of considerably lesser strength than the 1859 event (a Disturbance storm time (Dst) value of -589 nT was registered in 1989 compared to a Dst of -1760 nT for the 1859 event (Lakhina et al. 2005). [The Dst index is a measure of geomagnetic activity used to assess the severity of magnetic storms. It is expressed in nanoteslas and based on the average value of the horizontal component of the Earth's magnetic field measured hourly at four near-equatorial geomagnetic observatories. *A negative value is shown when the Earth's magnetic field is weakened*].

Fortuitously, that solar storm hit in the middle of the night: if it had hit during peak load conditions, grid closure may have cascaded into the USA (Riswadkar & Dobbins 2010).

It caused over 200 power anomalies in North America. These included: the blackout of the province of Québec in Canada (*due to a voltage depression over a 90-second period that could not be mitigated by automated compensation equipment*); melting of power transformers in New Jersey (*including the failure of a transformer at a Nuclear Power Plant*); voltage swings at major substations; and generators tripping and going out of service (US NRC 2008).

A utility firm placing a top priority order for the replacement of a damaged generator step-up transformer as a result of the 1989 event was told it would take almost 2 years to fulfill. Luckily, a spare was available which was installed within 6 weeks (Marusek 2007). Within 25 months of the March 1989 storm, 12 Nuclear Plants had transformer incidents that were suspected as being delayed failures caused by that storm (Kappenman 2011).

The direct cost of the March 1989 solar storm was over $2 billion [£1.245 billion]. The cost of protecting key areas of the US grid against EMP would be $150 million [£94 million] (Riswadkar & Dobbins 2010). The costs would be greater for smart grids as present grid designs have unknowingly increased GIC risks and their potential impacts (Kappenman 2011). Measures to reduce risk are already being put in place by governments to secure their "*critical electric infrastructures*" (EIS 2011, 2010).

Solar storms of equal, or greater, magnitude to that of the 1989 solar storm have occurred in 1859, 1872, 1882, 1903, 1909, 1921, 1928, 1938, 1958, 1989 (Gonzalez et al. 2011). It appears more cost-effective to create robust smart grids now than to have to do so in retrospect. Solar events are not particularly rare.

Smart Meters are more vulnerable to solar storms than the meters they replace, as the chips for their integrated circuits are easily damaged by solar EMPs/geomagnetically induced currents (GICs).

Research indicates that large GICs are also possible at low-latitudes, as well as at high latitudes (Kappenman 2011).

It appears that smart grids will need to be protected against solar EMP to comply with the International Infrastructure Security Roadmap.

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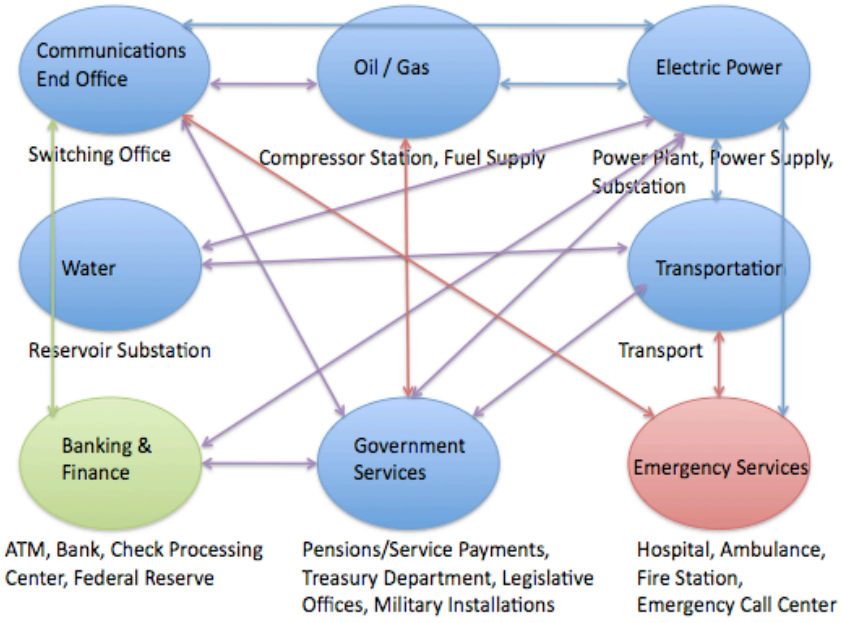
Sensitivity to geomagnetic storms



The economy is sensitive to geomagnetic storms due to a network of interdependencies. [Adapted from original graphic by US Department of Homeland Security].

The US National Research Council (NRC 2008) states, "*Because of the interconnectedness of critical infrastructures in modern society, the impacts of severe space weather events can go beyond disruption of existing technical systems and lead to short-term as well as to long-term collateral socioeconomic disruptions*."

"*There is limited time to upgrade national electric grids to avoid solar flare-induced, global scale burn out*." Arbuthnot et al. (2010).

The consequences of such an event could be very high, as its effects could cascade through other systems dependent, either directly or indirectly on electricity. It is therefore vital that smart grids and Smart Meters are robust and able to withstand such threats.

Distribution of drinkable water could be compromised, as could cooking and food refrigeration facilities, fuel supply, heating, lighting, Internet and telephone communications, sewage disposal and transport (fuel pumps require electricity to work). Banking, government, medical treatments and emergency services could also be affected to various degrees.

The effects of a solar super storm, as predicted for 2012/2013, could take many years to correct and severely damage national economies unless appropriate measures are taken in time.

UK Government Expert Opinion

The UK Government is aware of the threat of solar storms and has already taken various contingency measures, including allowing some transformers to be switched off if necessary (Connor 2011).

The UK's National Risk Register (NRR 2010) has contingency plans to cope with a complete national outage and regional outage of electrical supplies. It states that "*In the event of a national outage (which has never occurred), and provided there had been no damage to the system, the objective would be to restore supplies throughout Great Britain within three days*." Some question whether such measures are adequate.

The UK Government's chief scientific adviser when speaking at the annual meeting of the American Association for the Advancement of Science (AAAS) in Washington DC earlier this year noted that solar storms could cause catastrophic damage to the world's economy.

"*The potential vulnerability of our systems* [to space weather] *has increased dramatically. Whether it's the smart grid in our electricity systems or the ubiquitous use of GPS*."
Professor Sir John Beddington, UK Government's chief scientific adviser (Brewster 2011).

Similar concerns were raised by UK Defence Secretary, The Right Honourable Liam Fox MP, in 2010 when he warned that with our heavier reliance on technology our way of life is now more at threat from such solar events than ever before (EIS 2010).

It is estimated that the cost of what Professor Sir John Beddington call a potential "*global Katrina*", caused by the increased solar storm activity could be up to $2 trillion (£1.2 trillion) as a result of various technologies being knocked out unless suitable precautionary measures are undertaken.

Whilst severe solar storms occur infrequently, they have the potential to create catastrophic long duration impacts on electricity supply and end users (US NRC 2008). Less severe storms can also cause significant damage.

As Smart Meters are more vulnerable to stray high-energy electrical fields than the units they replace, a delayed rollout till after 2014 might be worth considering for this reason alone.

Erinmez et al., (2002) noted that whilst the power transmission systems of UK's National Grid are "*generally designed to operate reliably under challenges mainly related to terrestrial weather conditions … the measures* [used to increase their] *robustness have also made transmission systems more vulnerable to the risk of space weather through geomagnetic storm activity*."

US Expert Opinion

In similar vein, Jane Lubchenco, head of the National Oceanic and Atmospheric Administration (NOAA), is on record as having said at the AAAS 2011 meeting that the US also needs to be better prepared than at present to avoid loss of electrical power and communications as a result of solar flares.

She stated that "*This is not a matter of if, it's simply a matter of when and how big. We have every reason to expect we're going to be seeing more* [potentially harmful] *space weather in the coming years, and it behooves us to be smart and to be prepared*."

"*Many things we take for granted today are so much more prone to the effects of space weather than was the case during the last maximum*," Lubchenco declared (Moskowitz 2011a). The challenge faced may increase as the World is likely to become more 'technologically dependent' as it edges towards 2013 and other periods of solar maxima – *it appears wise to start 'future proofing' technology now and industry needs help from governments to do so*.

"*What's at stake are the advanced technologies that underlie virtually every aspect of our lives*." Tom Bogdan, Director of the US Space Weather Prediction Center. He also mentioned that forthcoming individual solar events could be particularly powerful (Lovett 2011).

These echo the earlier thoughts of John Kappenman at the 2008 US National Research Council workshop on the societal and economic impacts of severe space weather events (US NRC, 2008). He additionally noted that lack of preparedness could result in "*significant societal impacts and with economic costs that could be measurable in the several-trillion-dollars-per-year range*."

Seven months after that meeting, NASA found a giant breach in the Earth's protective shield (Phillips 2008) that will increase the impact of solar storms above those discussed in the report above – *present author's comments.*

Need for robust smart grid solutions to space weather

Since 1989, development of open access on transmission systems has encouraged the transport of large amounts of energy across grid infrastructures to benefit economic returns by delivering less expensive energy to areas on demand.

That rationalisation, however, taken alongside the increased likelihood of multiple equipment failures from solar events has increased the risk of collateral damage – *sophisticated items, such as Smart Meters (and satellites used for smart grids), are more likely to be damaged by such events than the equipment they replace. Smart appliances too might be more easily damaged than their conventional counterparts?*

The vulnerabilities of electric grids to EMP events are now being addressed in the USA by the US National Security Working Group (NSWG 2011). Also in February 2011, US Congressman Trent Franks proposed for federal legislation the H.R. 668 SHIELD Act, "*to amend the Federal Power Act to protect the bulk-power system and electric infrastructure … against natural and manmade electromagnetic pulse (`EMP') threats and vulnerabilities,"* (Franks 2011).

Further support for increasing the robustness of smart grid systems worldwide – *as related to space weather* – beyond what is already being achieved might prove appropriate?

Riswadkar & Dobbins (2010) propose the hardening of system and critical assets through installing circuits or passive devices to prevent, or reduce, geomagnetically induced currents (GICs) flowing into electrical grids. Both aging transformers & grid infrastructure and smart grids create mitigation challenges.

The risk of solar flares to the low orbiting satellites that can be used for smart grid data transference too has to be taken into consideration – *these too should be hardened*. X-class flares, which are on the increase till 2013 (Moskowitz 2011a), can cause their orbital decay.

Some locations where Smart Meters will be installed are more vulnerable than others. In particular, electrical grids are at greater risk from the effects of geomagnetic activity in areas where igneous rock (such as granite) is present (Odenwald, 2009). [The high resistance of such rock encourages geomagnetically induced

currents (GICs) to course through power lines situated above them raising risk of damage].

At the very least, as a precautionary measure, it is suggested that consideration should be given to retaining existing electromechanical rotating-disk meters (which are more resilient to space weather than present Smart Meters) till after the solar maxima of 2012/2014 when risk begins to subside. Grids should be appropriately upgraded as finances allow and ideally hardened to increase their resilience.

"*[The risk we face from solar events] is slightly scary, and I think properly so. …We've got to be scared by these events otherwise we will not take them seriously*."
Professor Sir John Beddington, the UK Government's chief scientific adviser (Moskowitz 2011a).

Shielding just 10% of critical infrastructure could reduce anticipated damage from EMP events considerably (The Sage Policy Group, 2007). The present author suggests that as a basic minimum at least 20% should be protected before the main risk periods in 2012-2013 - ideally protection levels should be 'As High As Reasonably Achievable' (AHARA).

Precautions taken to protect smart grids and technology from natural EMP events will also help protect them from EMP events by terrorists/rogue nations.

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