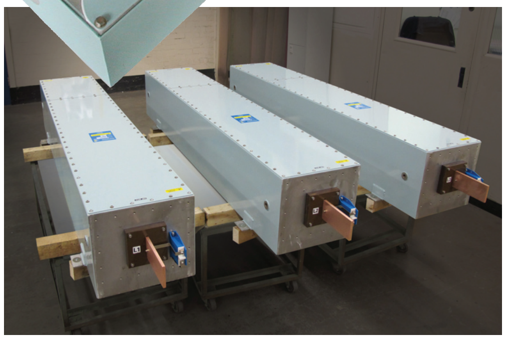
The impact of solar superstorms on engineering infrastructure and how to protect it



Paul Currie, sales and marketing director, MPE Ltd talks about how to protect engineering infrastructure from solar activity

The sun has always been benign towards the Earth, providing light and heat essential to the growth of civilisations. However, as our technology has advanced, so the sun has become a threat too, with its constantly changing surface plasma creating magnetic storms. Coronal mass ejections (CMEs) are large bursts of solar wind plasma carrying intense magnetic fields, and the biggest in modern times was the Carrington Event of September 1859, named after the English amateur astronomer Richard Christopher Carrington, who observed a huge solar flare on the day before the superstorm broke.

Near misses in recent years have caused major technological damage, for example the collapse of Quebec's electricity grid in March 1989 at a total cost to the Canadian government of $12.7 billion, a 1956 event which was the highest recorded for atmospheric radiation, and the highest recorded radiation events measured on spacecraft in August 1972, October 1989 and October 2003.

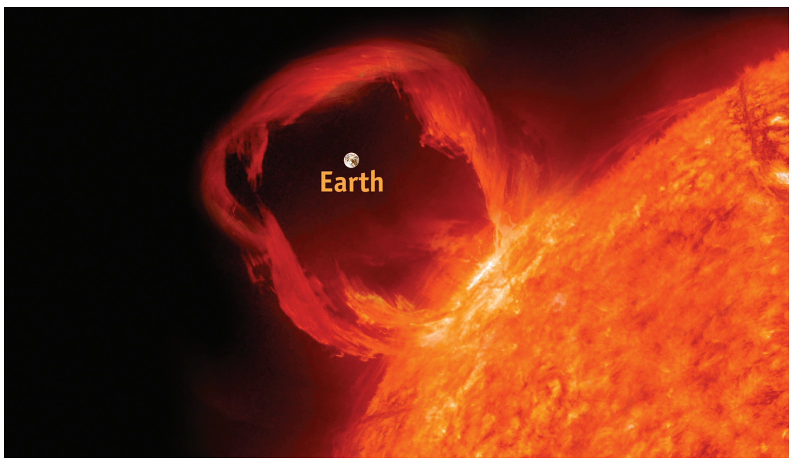
Whilst spacecraft, satellites and aircraft will of course lie first in the path of any geomagnetic storm heading in our direction, at ground level geomagnetically induced currents (GICs) will arrive on all interconnected architecture simultaneously at high speed. Hence protection afforded to the critical nodes of the electricity grid – the super grid transformers – would not prevent GIC transients from causing huge damage to equipment at local sites elsewhere.

Solar activity follows an 11-year cycle, with the most intense events occurring near the cycle's peak, so therefore we should take the threat as seriously as possible.

The geomagnetic field will affect large regional areas and induce transient currents to flow in the cables of electrical distribution systems. The amplitudes and waveshapes of these transients are affected by the geography and topography of location, as well as the electrophysical characteristics of transmission lines. The low thresholds of susceptibility of modern equipment systems to fast, high-amplitude transients make GICs a clear and present danger to the continuity of critical infrastructure services. The most technologically advanced countries should have prognostic modelling to predict which of their strategic locations run the highest risk of transients coupling on to exposed electrical cables.

Indeed the mitigation of solar superstorms necessitates a number of technology-specific approaches which come down to engineering out as much risk as is reasonably possible, and then adopting operational strategies to deal with the residual risk. For the former, enhanced surge protectors – above and beyond those installed for lightning – can harden national electricity grids against GICs. For the latter, space and terrestrial sensors are required to monitor the superstorm's progress from its early stages as intensified activity on the sun's surface through to its final impact on the Earth.

With all this in mind, US Republican Congressman Trent Franks of Arizona and former House Speaker Newt Gingrich introduced a Bill in the House of Representatives in June 2013 to amend the Federal Power Act to protect the US grid. Called the SHIELD Act, an acronym for "Secure High-voltage Infrastructure for Electricity from Lethal Damage" Act, the Bill is pushing the Federal Government to install grid-saving devices, surge protectors that could save the transformers and power system from electromagnetic pulses. The Bill centres on protecting high-voltage transformers serving towns and cities, principally because a June 2012 Department of Energy report identified these as a key vulnerability in the grid, citing volatile pricing for copper and electrical steel raw materials and a lead-time for replacement that can stretch to 20 months. These complex voltage switching devices namely weigh up to 400 tons, cost millions of dollars and are made in only a handful of facilities Stateside.



Nevertheless the provisions of the SHIELD Act, although far-sighted and economically sound, do not address the issue of high-speed GIC transients arriving simultaneously en masse and wrecking the equipment in local assets such as computer rooms, communications hubs, base stations, data centres, public utilities, process plant, banks and air traffic control towers.

So, to protect such engineering infrastructure and equipment systems at a local level, one of the most viable solutions is MPE's high-reliability High-Altitude ElectroMagnetic Pulse (HEMP) filters to MIL-STD-188-125. Why? Because this technology is transferred from the defence arena (nuclear blasts high in the atmosphere) to extreme space weather applications (CMEs). Characteristics common to both these situations, apart from the dangerous levels of radiation each creates, is that general EMP events will hit all electrical systems simultaneously and can never be constrained within national borders: numerous countries or regions may be unfortunate enough to be affected and caught unawares by the suddenness of a strike.

MPE has pioneered electrical filters for the protection of critical defence and national infrastructure assets from the effect of Nuclear ElectroMagnetic Pulse (NEMP) since the mid-1980s, when their hallmark integrated solution combining metal oxide varistors (MOVs), capacitors and inductors accorded with the NATO specifications of the day. The same product design philosophies which will successfully attenuate high-speed, high-amplitude NEMP currents may be applied to safeguard against the effects of GICs.

These products incorporate an integrated combination of staged diversion and attenuation elements, most usually in the form of surge arrestors and full frequency spectrum filters. They incorporate MOVs as a front-end transient suppressor, giving an ultra high-speed response to arrest the incoming pulse. Then the bespoke inductive and capacitive elements of the filter give highly effective full frequency spectrum protection against induced pulse currents at the cable entry points of AC mains power, telephone, data and control lines that are based on long-line copper wire technology.

MPE's military products are designed to be of high reliability and to survive multiple exposures to peak NEMP currents derived from the highest yield weapons. These filters attenuate the ultra-fast high bulk currents induced in exposed cables and wires to levels below the damage thresholds of susceptible electronic equipment systems and far exceed the requirements for hardening commercial assets against the effects of GICs.

A practical consideration is that the coupled circuit design featured by MPE creates a far more compact unit for installation in tight spaces – down to a quarter of the size of conventional systems in which each line is wired up to a separate filter – whilst supporting easy inspection and maintenance. Those size and weight advantages afford significant shipping, installation and space benefits to installer and user alike.

In conclusion, according to a report produced by Lloyd's in co-operation with Atmospheric and Environmental Research, solar superstorms of Carrington magnitude will occur once every 150 years, so our next one is now overdue, and the effects of the event on human life would be more devastating than ever before, owing to our dependence on the two-edged sword of technology.

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