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Solar Storms and Their Impacts on Power Grids: What Consequences for (Re)insurers?[1]

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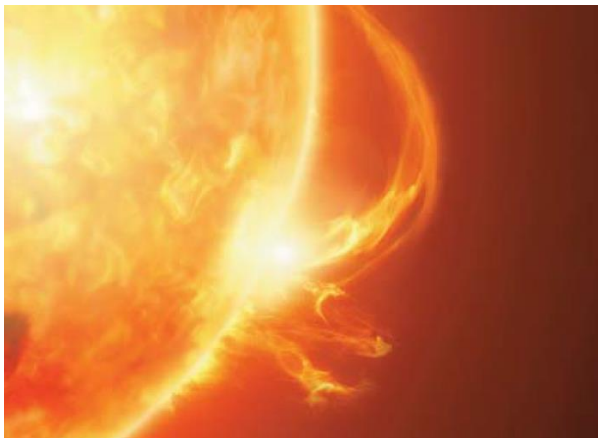
Solar storms and their impacts on power grids

Solar storms are events which result from explosions on the surface of the Sun. They may cause disruptions to a wide range of activities and devices, including radio communications, GPS, radar systems, satellites, electronics, railway signalling systems and pipelines.

Figure 1. Solar eruption with coronal mass ejection



Source: NASA

The most severe solar storms can generate coronal mass ejections (CMEs). CMEs are vast clouds of seething gas, charged plasma of low to medium energy particles with imbedded magnetic field, which are ejected from the Sun. They are correlated with the 11-year solar cycle for sunspots. However, large CMEs can occur anytime during the cycle. When a CME reaches the vicinity of the Earth, its magnetic fields interact with Earth's magnetic field (the magnetosphere) and distorts it. This creates the beautiful aurora borealis.

Figure 2. Picture of an aurora borealis observed from space

Source: NASA

According to Faraday's law of induction, these time-varying magnetic fields also create differences of electric potential in the ground that can reach several volts per km. When a solar storm hits the Earth, electricity transmission lines whose extremities are grounded to the earth provide a shortcut between points with very different electric potentials. This drives currents called geomagnetically induced currents (GIC).

[1] This article summarises a SCOR paper published by the author in February 2014. Texts appearing in SCOR papers (as well as this article) are the responsibility of their authors alone. In publishing such articles, SCOR takes no position on the opinions expressed by the authors in their texts and disclaims all responsibility for any opinions, incorrect information or legal errors found therein. Available at http://www.scor.com/images/stories/pdf/scorpapers/sp28.pdf.

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GICs may damage grid transformers in the bulk power system (BPS), because these transformers are designed to deal with AC currents, not DC currents. DC currents may cause overheating of transformers and the production of gases in the insulating oil, damaging them up to the point of failure. Moreover, even before GICs damage any transformer, they may increase their reactive power consumption and cause a voltage collapse. Furthermore, harmonic currents may cause the tripping of protective systems on the grid. This can also cascade into the collapse of parts of or even the whole grid.

Such disruptions have already been observed in relatively recent years, notably in March 1989 when a solar storm collapsed the Hydro-Québec power grid in less than two minutes, resulting in the loss of electric power to more than six million people for nine hours. However, no major solar storms such as the spectacular "Carrington storm" have been experienced in contemporary times. In 1859, when that storm hit the Earth, auroras could be seen in Cuba, and telegraph systems became unusable across Europe and North America,

While there are reasons to believe that a one-in-200-year solar storm would not be that different from the 1859 event, studies diverge as to what would be the impact on modern power grids.

Some of them foresee only rather limited disruptions. Thus, modelling done for the U.K. National Grid suggests that a Carrington-like solar storm [...] would only result in "temporary localised power interruptions" (National Grid, December 2012).

But other studies anticipate a major power blackout affecting millions of people for several weeks or more, with consequences reaching trillions of dollars. Among them, a study conducted in 2013 by AER concludes that a Carrington-level storm would deprive between 20 and 40 million people of electricity in the U.S., with durations of 16 days to one to two years, with economic costs estimated at US$0.6–2.6tn (LLoyd's & AER, 2013). The reason why power blackouts caused by solar storms, if triggered by the destruction of transformers (as opposed to being triggered by the tripping of protective equipment), may last for an extended period of time is that damaged transformers could neither easily be repaired *in situ* or replaced by new ones. Indeed, it takes several months to build a transformer (Office of Energy Delivery and Electric Reliability, 2012), manufacturing capacities are limited to around 70 units per year (Aon Benfield, 2013) and spare inventories are low.

In light of such doomsday scenarios, solar storms are increasingly on the radar of public authorities. In the U.S., on 16 May 2013, the Federal Energy Regulatory Commission (FERC) issued a rule related to solar storms. This rule mandates the development of reliability standards requiring owners and operators of the BPS to take two actions. First, they should implement operational procedures to mitigate the effects of solar storms when alerts are sent by agencies such as the Space Weather Prediction Center (SWPC), which broadcasts solar storm forecasts. Second, they should conduct assessments with a view to developing and implementing action plans as needed (FERC, 2013).

What consequences for (re)insurers?

In spite of the economic costs anticipated by some studies, and in spite of the damage caused by recent events such as the 1989 storm, very few insurance policies currently mention solar storms[2].

Consequently:

- Solar storms would arguably be covered by "all risks" policies, given the absence of any exclusion clause.
- Solar storms would arguably not be covered by "named perils" policies, given the absence of any inclusion clause, unless they indirectly provoke one of the perils named in the contract (fire, explosions, etc.).

Given this, the remainder of this article attempts to review potential impacts from solar storms on various types of insurance policies.

- **Property insurance**

Property insurance policies may be triggered by a major solar storm. In that case they may cover:

[2] The author has only found one recent insurance policy for a Telecom operator in the Middle East, containing the following exclusion: "Excluding loss/damage due to solar disturbances viz, solar tsunami".

- physical damage incurred by the insured,
- business interruption caused by such damage,
- business interruption caused by physical damage incurred by a supplier/service provider/client.

In all cases, someone needs to incur physical damage for the policies to be activated. In this respect, it is interesting to keep in mind that a major blackout could happen without being caused by property damage to the grid: the loss of reactive power or the tripping of protective equipment may result in a partial or full collapse before transformers suffer from overheating.

Physical damage incurred by the insured

Generating companies/transmission system operators

A major solar storm could damage transformers up to the point of failure, if the grid does not collapse before. The destruction of a transformer would be indemnified by the property cover of the owner: the generating company or transmission system operators (TSOs). The typical cost of a transformer is US$10m. The overall cost would depend upon the number of transformers affected: around 13 for the U.K. in National Grid's simulations of a Carrington scenario (Royal Academy of Engineering, 2013), and hundreds of them in more pessimistic studies.

Large corporate clients

A power outage, especially if prolonged, may cause physical damage to large corporate clients. This is the case for manufacturers using certain types of processes. For instance, aluminium melting furnaces will already sustain irreversible physical damage after 4–5 hours without electricity (Bruch *et al.*, 2011, p. 12). Property insurance policies would typically cover such damage.

Retail consumers

Due to a power blackout, retail electricity consumers may suffer from various kinds of physical damage: loss of food in freezers, frozen water pipes, etc. Traditional property covers may cover some of this damage.

Business interruption

If the insured suffered both physical damage and a loss of revenue due to this physical damage, this loss of revenue would fall under the "business interruption" (BI) extension of its property cover, such an extension being widespread, not to say systematic, for large corporate insureds in developed countries.

Generating companies

If a generating unit resulted being cut off from the grid for a period longer than the waiting period stipulated by its insurance policy, the amount of the claim would correspond to the net loss of revenue of the generating company. This amount would partially depend on the spot price of electricity during the period when the power plant would not be able to operate. This spot price might behave unexpectedly given the circumstances, adding uncertainty to the amount of the claim.

TSOs

Similarly, TSOs not being able to transport power to end customers (large corporate or retail) because of physical damage to their own property could claim loss of revenue. Contrary to generating companies, they would typically be paid a fixed sum for each MWh they transport.

Large corporate clients

Physical damage directly suffered by large corporate electricity consumers (such as aluminium producers) may halt production for a certain period of time. If this period is longer than the waiting period stipulated by the insurance policy, BI covers could be triggered.

Service interruption/Contingent business interruption

In a severe solar storm-induced blackout scenario, many companies relying upon electricity for their operations would suffer from disruptions and loss of revenues, even if they do not incur physical damage themselves. In most cases these losses of revenues would be eligible for coverage under "service interruption" extensions of property

covers, which are also widespread, not to say systematic, for large corporate insureds in developed countries. As a matter of fact, the purpose of these extensions is precisely to cover insureds against loss of revenues caused by the interruption of services such as power, gas or water supply.

Service interruption extensions generally include the same provisions as BI extensions in terms of waiting period, minimum combined deductible and indemnity period. However, the limit is typically 10 per cent to 15 per cent as high as the limit applicable to property and BI losses.

In such a situation, insurers may face an "accumulation" problem, with a large number of policies (virtually all policies including a service interruption extension in the area affected by the blackout) being triggered at the same time.

Insurance policy wording

Since the awareness about solar storms remains limited among risk managers, brokers, insurers and reinsurers, policy wording does not take this risk into account. This is a real source of uncertainty as to the triggering or not of insurance policies, all the more so since court decisions may bring their lot of surprises.

Notion of physical damage

As stated above, the triggering of property covers, including BI/service interruption/CBI extensions, requires physical damage to be incurred (as far as service interruption and CBI extensions are concerned, this damage would not be incurred by the insured itself).

But an imprecise wording may cause the insurer to pay claims even if there is no such "physical damage". Suriano & Haas (2012) mention a series of cases judged by U.S. courts which illustrate this.

Notion of electricity supplier

The simultaneous triggering of the service interruption extensions of commercial/industrial clients dependent upon electricity in a region affected by a prolonged blackout is one of the highest risks for insurers.

Hence the importance of the wording of these extensions. In particular, wordings may raise the question of whether generating companies and TSOs would all be considered by a court as "suppliers" of electricity. This is of particular importance for TSOs, which are likely to be the ones incurring physical damage on the grid.

- **Liability insurance**

A major solar storm could result in the impossibility for certain parties to perform their contractual obligations towards other parties, or even in damage caused by certain parties to other parties. For instance, a TSO may not be able to fulfil its contractual obligation to transport electricity. By doing so, it may also inflict damage to a third party, such as the aluminium producer mentioned earlier sustaining irreversible damage.

This raises the question of whether such parties would be held liable and their liability covers would be triggered.

At first glance, one could argue that a major solar storm would fall under the exception of *force majeure*. However, it does not seem possible to sweep aside any liability risk altogether.

Plaintiffs may try to show that the risks posed by solar storms to power grids were well known and that mitigation measures were available, with a cost–benefit ratio that would, in retrospect, look compelling.

They may challenge the idea that solar storms are unpredictable by pointing at existing space weather forecasts, which make it possible to identify CMEs one to four days in advance, even though the danger cannot fully be assessed more than 15 to 30 minutes before a solar storm hits the Earth. They may point at deficiencies in operational procedures meant to react to such events. In the absence of any such procedure, they may use the fact that some TSOs such as the U.K. National Grid have put in place comprehensive procedures as a proof that they could/should have done the same.

Until recently, it seems that no binding standard or regulation applicable to power grid operators specifically addressed the risks from solar storms. But the new FERC rule changes this situation: when the reliability standards are defined, failure by U.S. operators to comply will most certainly lead to liability in case of the occurrence of a superstorm with heavy consequences. It is not clear whether such liability would extend to operators from outside the U.S. Although they would not be legally bound by these standards, they may be considered negligent for not having implemented them.

If generating companies or TSOs were held liable for a blackout, their liability covers could be triggered. However losses for (re)insurers would be limited by two factors. First, contrary to electricity consumers, the number of generating companies and TSOs in a given area is relatively small. Even if they were all held liable, losses shouldered by their (re)insurers would be capped by the limit per cover times the (small) number of insurance policies concerned. Second, liability insurance policies for generating companies and TSOs usually only cover liability arising from bodily injury, personal injury and property damage. Consequently, these policies would not cover business interruption losses suffered by industrial electricity consumers merely due to their inability to operate without electricity. They would only be triggered if the industrial electricity consumers suffered physical damage (as can be the case for aluminium producers for instance).

- **Wider impacts in the event of a prolonged blackout scenario**

If a solar storm were to cause a prolonged blackout, indirect impacts would cause severe losses on top of direct losses. For instance, disruptions suffered by firefighting units (lack of fuel, lack of water) may reduce their capabilities, which may result in more destructive fires. After days or weeks of power outage, distressed populations may resort to looting.

For insurers, losses on the P&C liability side may be compounded by losses on the asset side. For instance, a prolonged blackout affecting the north-eastern part of the United States would certainly affect stock markets. The insurance industry, which holds investments worth trillions of dollars, would be affected.

These wider impacts show that solar storms should not be the concern only of (re)insurers' underwriting power, BI or CBI/service interruption policies. If one gives faith to the prolonged blackout scenario supported by some studies, all (re)insurance companies would be heavily affected by a major solar storm. Consequently, the industry as a whole should engage with governments, power grid regulators, power generating companies and TSOs in order to raise awareness and promote concrete answers[3].

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[3] The report on which this article is based outlines 16 recommendations for (re)insurers, touching upon risk management, underwriting and engagement with governments.