



Special Reprint

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We Interrupt Our Normally Scheduled Issue

To Bring You The Case for Solar Weather Derivatives

A Special to The Desk by Andrew Hyman, PricewaterhouseCoopers

About two weeks ago we had a serendipitous conversation with Andrew Hyman, a research director with the PricewaterhouseCoopers Global Energy & Utilities Industry practice, on a somewhat obscure topic. Sunspots. Solar flares. And other, other-worldly phenomenon known to give folks in the power business something else to worry about.

Within a few days after that initial conversation, Hyman had rationalized a pretty solid case for solar weather derivatives. Earlier this week he presented to The Desk this exclusive report supporting such a market. The additional coverage and background material found on this issue is just the tip of the iceberg. Feel free to contact us or Hyman for further information.

– The Editor.

Under regulation, electric companies passed along unexpected costs from natural disasters to customers. With competition, unpleasant surprises can drive away customers who can now choose suppliers. For example, customers who can generate their own power from a sheltered gas line will have little incentive to seek business from a power company that tries to pass on costs from long lines that go down in a hurricane.

In some states, utilities still pass all their costs through to customers, but that situation is becoming increasingly rare. Deregulation, however, need not mean disaster. Effective risk management can minimize the financial impacts from natural hazards. New risk-management tools can enable electricity suppliers to protect profits from space and weather events that can bring down transmission and distribution systems.

In 1989, a geomagnetic storm shut down Hydro-Quebec's transmission and distribution system for nine hours. On March 13, 1989, geomagnetically-induced currents from magnetic storms crashed a transformer on one of Hydro-Quebec's main transmission lines that precipitated a collapse of the entire power grid—a loss of more than 21,000 MW of power. The system went down in 90 seconds. Restoring it took nine hours, while six million people had no power.¹ The storm was a function of a high level of solar activity, known as a solar maximum. From now until 2002, the world is in the midst of another solar maximum and there is no reason similar storms won't recur.

According to a study by Oak Ridge National Laboratory, a storm of slightly larger magnitude than the Quebec storm could

create direct losses of \$3 billion to \$6 billion (in 1988 dollars) on the United States' Gross Domestic Product.² In fact, a larger storm occurred on November 13, 1960.³ That figure does not take into account the potential disruption of transportation, fire protection and public safety services.⁴ Some risk assessments infer that a storm of similar magnitude could affect the reliability electric service as much as Hurricane Hugo did in 1989.⁵

In fact, since the Quebec outage, the power grid has become more vulnerable to geomagnetic storms. Tripping the power grid at an interconnection could cause a cascade of problems throughout the system.⁶ Deregulation and the rising demand for electricity have led to increased transmission over longer distances, which because of the physics of induced currents, makes these long lines more vulnerable to geomagnetic disturbances.

Another complicating factor is that, unlike localized distribution problems such as lightning strikes, geomagnetic storms affect large areas. Failures could occur simultaneously on many systems, which would reduce the possibility of backup power coming from outside one region, as can happen when lines are downed from localized storms. In addition, many transmission systems are operating closer to their limits than when the lights went out in Quebec in 1989.⁷

Utilities can take some steps to minimize the effects of solar weather. These actions include: reducing power flow through critical transformers, reducing the distance that electricity flows (because longer lines are more susceptible to problems) and resetting relays within systems to be less sensitive.⁸ In addition, capacitors can be added to prevent current inflow into lines by diverting the problem into another point on the line.⁹ But, most of these measures, such as choosing to generate locally rather than buying long-distance power during a storm, depend on reliable geomagnetic forecasts. Although forecasts are improving, they are primitive in comparison to modern-day meteorology techniques. NOAA (National Oceanic and Atmospheric Administration) is able to provide warnings about one hour in advance of major geomagnetic disturbances. The long-range forecasts are less reliable.

The utility industry has not totally ignored the risk. Nearly a decade ago, EPRI (Electric Power Research Institute) formed a monitoring network called SUNBURST. Real-time readings are shared among participating utilities across the U.S. and Canada and from South Africa as well. EPRI Report TR-100450, Proceedings: Geomagnetically Induced Currents Conference (Palo Alto, June 1992), has further information.

The limited scope and quality of forecasts – and the limited measures that can be taken against large disturbances -- point to the need to financially manage the risk of solar weather. Why not create geomagnetic derivatives? This would allow power companies to purchase a level of geomagnetic exposure in the marketplace to counter risks that may be encountered in the atmosphere.

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Background on Geomagnetism

Solar Maximum

The risk of magnetic storms is greatest during a period at or near the solar cycle known as the solar maximum. The solar maximum is the time during the solar cycle when the maximum number of sunspots are visible on the sun's surface. Sunspots are darker, cooler, regions on the sun's surface with strong magnetic fields.

The solar cycle describes the change in solar activity based on the numbers of sunspots measured on the sun's surface, with an average of about 11 years between maximum occurrences.

Magnetic Storms

Solar flares, more common during the solar maximum, eject portions of the solar atmosphere into space at high speeds. These particles hit the earth's magnetosphere¹⁰ and distort it, disrupting the "normal pattern of electric currents flowing in the ionosphere and the magnetosphere."¹¹ The disruption creates disturbances of the magnetic field at the earth's surface known as magnetic storms. The after-effects of these storms can last for up to a week or more.¹²

Geomagnetically Induced Currents

During space and weather disturbances, large fluctuating currents from up to one-million to several hundred million amperes, flow through the ionosphere producing auroras and heating the atmosphere. The fluctuating magnetic fields induce currents to flow in large-scale conducting bodies, such as crustal rocks, the ocean and long structures such as electric cables, pipelines, and undersea telecommunications cables.¹³ The ionospheric currents induce currents in the earth's surface known as geomagnetically induced currents (GICs). Rocks vary in their ability to carry current, with igneous rocks being among the most resistant.

When current can't flow through the rocks, it looks for the easiest path, which more often than not are man-made conductors on the earth's surface, such as pipelines and cables. These fields can set up potentials on the order of 3-10 V/km, which can create considerable potential difference on long lines.¹⁴ The transformers in the electric system are intended only to have alternating current flow through them, but magnetic storms induce direct currents in the lines and transformers.

The additional current pushes the transformer's magnetic flux outside of the iron core within the windings of wires. Transformers are not designed for these stresses. The electric power is converted to heat, raising the temperature of the transformer and the oil bath in which it sits. Increasing temperatures can lead to oil fires and melt down of transformer components, as well as burning transformers up.¹⁵ In addition, because a geomagnetic storm is a global phenomenon, it can affect a number of transformers on the same grid simultaneously, reducing the ability of grid systems to redirect current through other transformers when one goes down. Even if the transformers don't fail, the saturation currents decrease transformer life.

When a power system crashes due to transformer failure, there could be significant startup problems, because of the large area affected. Steam plants need a long time to build up the necessary pressures for generation following a shutdown. Hydro Quebec was fortunate that most of its plants were hydroelectric, which reduced startup times down to nine hours. Non-hydro plants can take days to restart.¹⁶

Another problem that could slow down recovery: Transformers are very expensive. Large transformers can cost up to \$10 million and have lead times of up to two years for orders and delivery. Since such failures are rare, most power companies do not stock extensive collections of spares. Lack of transformers can render power plants inoperable from the blackout. In addition, a surge of power is needed to start up all the appliances and machinery that were rendered inoperable. Startup requires power above the normal operating load, which can be disastrous if the appliances for countless households are starting up simultaneously.¹⁷

The solar maximum could have significant implications for the power system in California due to the underlying market problems and tightness of both generation and transmission capacity. The Pacific Northwest could be a high-risk area for magnetic disruptions due to its confluence of igneous rock (much of volcanic origin) and relatively high geomagnetic latitude in the United States. It is considered a GIC-susceptible region of the country and suffers from higher than normal rates of generation that step up transformer failure, which may be influenced by geomagnetically-induced currents, although the verdict is not yet in.¹⁸ This could affect the interconnections throughout the Pacific Northwest.

Given the tight situation in the California and the current flows of power, traders may wish to take solar storm forecasts into consideration when analyzing power flows and prices in that tight market. In addition, Quebec, much of Ontario, Labrador, Manitoba, Sweden and Finland also share the risk factor of being far north and underlain by igneous rock, which points to the need for a **global** risk-management tool. In the Southern Hemisphere, New Zealand and parts of Australia and South Africa are also at risk.

Geomagnetic Derivatives/Futures

The risks facing the electric transmission and distribution system by Solar Cycle 23 are considerable. Although the risk is unavoidable – man can not alter the sun's behavior – it is not unmanageable. The electric power business has recently taken up using weather derivatives to manage volatility in temperatures. There is no reason the industry can not use derivatives to manage the risks of solar weather.

In order to develop a derivative contract, a standard measure of magnetic disturbances is needed. One of the most widely available indices is the Kp index.

The Kp index is a "three-hour planetary geomagnetic index of activity generated in Gottingen, Germany, based on the K Index from 12 or 13 stations distributed around the world."¹⁹ The K Index is, "a three-hourly quasi-logarithmic local index of geomagnetic activity relative to an assumed quiet day [quiet as in no magnetic storms] curve for the recording site. Range is from 0 to 9. The K index measures the deviation of the most disturbed horizontal component of the magnetic field. Magnetic forces are exerted in three dimensions.

The K's range from 0 (a quiet day) to 9 (maximum disturbance) in 28 steps:

0o, 0+, 1-, 1o, 1+, 2-, 2o, 2+, ..., 8o, 8+, 9-, 9o

The integral numbers are divided into thirds:

1- = .67

1o = 1.0

1+ = 1.33

2- = 1.67

2o = 2.0

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The Kp index removes all local effects and permits scientists to assess the overall level of solar effect on magnetic activity and to judge the intensity of storms and is used in generating predictions of storms, as well as measures of severity used in assessing threats to electric power systems. NOAA uses the Kp system in assessing threats to electric power systems.

NOAA has produced the space and weather scales to describe environmental effects of space weather phenomenon. The scales for geomagnetic effects on power systems are reproduced below:

Category	Effect	Physical Measure	Average Frequency (1 cycle = 11 years)
	Category Duration of event will influence severity of effects	Kp values* determined every 3 hours	
Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage.	Kp = 9	4 per cycle (4 days per cycle)
Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid.	Kp = 8, 9-	100 per cycle (60 days per cycle)
Strong	Power systems: voltage corrections may be required, false alarms triggered on some protective devices.	Kp = 7	200 per cycle (100 days per cycle)
Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage.	Kp = 6	600 per cycle (360 days per cycle)
Minor	Power systems: weak power grid fluctuations can occur.	Kp = 5	1700 per cycle (900 days per cycle)

* Based on this measure, but other physical measures are also considered.

The logical move would be to base a derivative, whether a futures, option or swap on the three Hour Kp index, which is the baseline used planning for system failure and is widely recognized and understood within the energy and geophysics community.

A Kp index derivative would have a good chance for success. It has many of the characteristics that a commodity needs to be successfully traded:

- 1) The Kp is standardized according a worldwide criterion.
- 2) The precise future level of Kp is uncertain
- 3) The index is impartially determined
- 4) There is a large market; geomagnetic storms can affect power systems all around the world
- 5) Public information on Kp levels is easily obtained

Trading a Kp index is no different than trading a degree-day index or another financial index. It is easily available. The only concern would be that the official worldwide index is not prepared

in real time. However, the NOAA and the U.S. Air Force collaborate on producing an estimated planetary K (Kp) index in real time.²⁰ This could serve as the basis for the contract.

Trading the Kp index would in many ways even be more liquid than weather derivatives, which have not traded very successfully in organized exchanges.

Atmospheric weather derivatives are localized. For example, trading cooling degree days for Chicago would not substitute in trading cooling degree days for Buenos Aires. This greater liquidity would bode well for an exchange-traded geomagnetic contract. In contrast, the majority of weather derivatives are structured products and not traded on exchanges.

The Kp index, however, is worldwide and Kp of 7 implies the same level of magnetic disturbance anywhere in the world. Of course, locations further north would be more heavily affected, but those basis calculations for those regions could be made based on readily available magnetic data sets. Generally speaking, experts consider the southern half of the U.S. as not having any significant risk exposure to GIC. Other basis factors that would come into play are underlying rock formations and proximity to ocean borne GICs that influence coastal regions. In making basis calculations, it would be wise to use EPRI's risk factors for the impacts effects of GICs on power systems:

- GGIC levels
- GGIC duration
- GLength of transmission line
- G"Tower Grounding Impedance"
- G"Ground Wire Resistance"²¹

It would make sense to have different contracts for different months, as the equinoctial months of March/April and September/October tend to have significantly greater solar activity than normal, and the solstitial months (June/July and December/January) have less activity. Approximately twice as many geomagnetic disturbances occur during the equinoctial periods compared to the solstitial periods. Consequently, separating the contracts by months makes logical sense.²²

Traders could base their analysis on the data sets, which go back to 1932. In fact, other geomagnetic data go back as far as 1868.²³ This is a longer record series than exists for many atmospheric records. In addition, traders looking for forecasting information, can rely on NOAA for basic weather forecasts. However, space and weather forecasting has been described as comparable to meteorology in the 1950s before the advent of satellites to observe the weather. The unreliability can make it difficult for electric companies to prevent problems resulting from storms, or utilities make overreact to a forecast.

Without accurate forecasts, utilities cannot take action to prevent transformer problems. However, if warnings are inaccurate or vague (as they often are) companies may alter system operations such as switching from cheaper long-distance power to local generation, at significant cost, only to find out the forecast was a dud.

Of course, some companies may not wish to directly trade Kp derivatives, but to purchase insurance policies to handle the risks posed by GICs. Insurance companies may be reluctant to enter such a market if they can not easily hand off the risk. A liquid market in Kp derivatives would allow them to hand off the risk and facilitate the development of insurance products designed to meet the needs of the utility business.

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