How likely is a space weather–induced U.S. power grid catastrophe? JASON weighs in

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A huge arc of charged particles breaks free from the Sun and hurtles millions of miles toward Earth. Within hours it hits Earth's magnetic field, which compresses under the onslaught. The changing magnetic fields induce electrical current on power lines that crisscross the landscape. These geomagnetically induced currents (GICs) snowball, causing magnetic saturation and overheating in power transformers. The protective electrical insulation of vital transformer systems that form the nodes of the U.S. power grid is damaged by the overheating until the transformer insulation finally breaks down, resulting in an internal flashover. For an event of sufficient magnitude that affects the electric grid over a wide area, transformers connected to the longer lines can be expected to fail. With multiple power lines in play and because of the deep interconnectivity of the power grid, like lined-up dominos, one transformer after another falters and fails. Failure rates quickly exceed the available reserve of spare transformers (any utility's typical infrastructure includes a 3–5% reserve to account for the 0.75% average annual failure rate of these systems). Suddenly, a mere space weather disturbance has evolved into a catastrophe: replacing hundreds of burnt-out transformers in the U.S. power grid could leave millions without power for months, perhaps years, leading to economic losses in the trillions of dollars.

Tasked by the Department of Homeland Security, *JASON* [2011] recently published a study that assesses the likelihood of a so-called "Kappenman worst-case scenario" [*Kappenman*, 2003], such as the one described above, focusing on space weather effects on the electrical grid. The JASON report also discusses how previous solar storms have affected power grids and what can be done to protect the U.S. electrical grid. Our ability to predict the interactions of two complex systems, space weather and the U.S. power grid, is clearly crucial to mitigating these dangers.

As an independent scientific advisory group that has provided consulting services to the U.S. government on matters of defense, science, and technology since 1960, JASON presents many findings and recommendations in this report that will sound familiar to the space weather community: There has been tremendous progress in space weather research and prediction capability. The primary drivers leading to GIC events are rather well understood, but predictions are dependent on aging research satellites (ACE, STEREO, etc.) rather than on a robust national infrastructure that is equipped to take advantage of the strengths of the participating agencies, such as the U.S. Department of Defense, NASA, and NOAA. Some key recommendations to rebuild the space weather infrastructure are straightforward, while others that deal with the alignment and relative roles of these agencies may be controversial and will require multiagency engagement and coordination to implement.

A step-up transformer typically located at power plants used to get the power out of the plant and into the transmission grid. These are potentially vulnerable assets during a GIC event and would fail en masse should a Kappenman worst-case scenario unfold. Photo courtesy of Haukur Asgeirsson.

The biggest question addressed by this report concerns the likelihood that a major space weather event will catastrophically affect the U.S. power grid. The report answers, "We agree that the U.S. electric grid remains vulnerable, but are not convinced that Kappenman's worst-case scenario is plausible…" This statement is based primarily on the fact that we simply do not know enough about how the power grid will respond under extreme space weather conditions. However, JASON's conclusion is not based on information that would exclude the catastrophic scenario from consideration. In fact, it may be surprising to an uninitiated reader of the report to learn that basic GIC protection mechanisms for important transformer assets have not already been implemented in the U.S. power system, even though other countries, such as Finland and Canada, have found it prudent, indeed necessary, to protect their systems and deploy protecting relays.

When interviewed, technology leaders of one U.S. power company as well as government agencies that deal with multiple power companies revealed the pressures on technologists not to include any mechanisms that might hurt the reliability of the power grid. Relays that are supposed to protect the transformers can register false warnings that shut off power when there is no actual danger to the system. Such unwarranted shutoffs are, of course, costly to the power companies and to the U.S. economy. This makes power companies extra sensitive to introducing any technologies, such as new GIC transformer protector relays, that might exacerbate such problems.

The top three worries of the power company do not currently include space weather, although they do acknowledge the urgent need for a better and more comprehensive understanding of the power grid. The power company recognizes that the grid is deeply interconnected and can amplify perturbations from localized sources. A key recommendation of the JASON report is to create such a comprehensive simulation of the electrical grid that would generate much-needed data and enable a properly quantitative and reassuring assessment of the likelihood of Kappenman's worst-case scenario.

References

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