

GEOMAGNETIC STORMS, EMP AND NUCLEAR ARMAGEDDON

An extreme geomagnetic disturbance is likely to shut down electricity grids for months or years and trigger nuclear disasters at reactors worldwide. Protective measures could be implemented now to avert the end of civilisation as we know it.

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There are nearly 450 nuclear reactors in the world, with hundreds more either under construction or in the planning stages. There are 104 of these reactors in the USA and 195 in Europe. Imagine what havoc would be wreaked on our civilisation and the planet's ecosystems if we had not just one or two nuclear meltdowns but 400 or more! How likely is it that our world might experience an event that could ultimately cause hundreds of reactors to fail and melt down at approximately the same time? I venture to say that, unless we take significant protective measures, this apocalyptic scenario is not only possible but probable.

Consider the ongoing problems caused by three reactor core meltdowns, explosions and breached containment vessels at Japan's Fukushima Daiichi facility and the subsequent health and environmental issues. Consider the millions of innocent victims who have died or continue to suffer from horrific radiation-related health problems ("Chernobyl AIDS", epidemic cancers, chronic fatigue, etc.) resulting from the Chernobyl reactor explosions, fires and fallout. If just two serious nuclear disasters, spaced 25 years apart, can cause such horrendous environmental catastrophes, how we could ever hope to recover from hundreds of similar nuclear incidents occurring simultaneously across the planet?

In the past 152 years, Earth has been struck by two extreme geomagnetic disturbances (GMDs) caused by solar superstorms. If a GMD of such magnitude were to occur today, in all likelihood it would initiate a chain of events leading to catastrophic failures at the vast majority of our world's nuclear reactors, quite similar to the disasters at Chernobyl and Fukushima but multiplied over 100 times. When our Sun ejects a huge mass of highly charged plasma (a coronal mass ejection, or CME) directly towards Earth, colliding with the planet's magnetosphere and outer atmosphere, the result is an extreme geomagnetic disturbance.

Since a GMD of such a potentially disruptive magnitude last occurred in May 1921, long before the advent of modern electronics and nuclear power plants, we are for the most part blissfully unaware of this threat and totally unprepared for its consequences. The good news is that there are some relatively affordable processes and protective measures which could be implemented to protect our civilisation from this "end of the world as we know it" scenario. The bad news is that, as of now, even though panels of scientists and engineers have studied the problem and the US Congress has voted a few times on bills related to electromagnetic pulse (EMP) strikes, our leaders have yet to approve and implement a single preventive measure.

Most of us believe that something like this could never happen, and, if it could, certainly our "authorities" would do everything in their power to prevent such an apocalypse from ever taking place. Unfortunately, the opposite is true. "How could this happen?" you might ask. "Is this truly possible?" Read and weep, for you will soon know the answer.

Nuclear Power Plants and the Electricity Grid

Our global system of electrical power generation and distribution ("the grid"), upon which every facet of our modern life is utterly dependent, in its current form is extremely vulnerable to extreme geomagnetic storms that tend to strike our planet on average about once every 70 years.

We depend on this grid to maintain food production and distribution, telecommunications, Internet services, medical services, military defence, transportation, government, water treatment, sewage and garbage removal, refrigeration, oil refining and gas pumping, and to conduct all forms of commerce.

Unfortunately, the world's nuclear power plants, as they are currently designed, are critically dependent upon maintaining connection to a functioning electrical grid for all but relatively short periods of electrical blackouts in order to keep their reactor cores continuously cooled so as to avoid catastrophic reactor core meltdowns and spent fuel rod storage-pond fires.

If an extreme GMD causes widespread grid collapse (which it most certainly will), in as little as one or two hours after each nuclear reactor facility's back-up generators either fail to start or run out of fuel, the reactor cores will start to melt down. After a few days without electricity to run the cooling system pumps, the water bath covering the spent fuel rods stored in spent fuel ponds will boil away, allowing the stored fuel rods to melt down and burn.¹

Since the Nuclear Regulatory Commission (NRC) currently mandates that only one week's supply of back-up generator fuel needs to be stored at each reactor site, it is likely that after we witness the spectacular night-time celestial light show from the next extreme geomagnetic disturbance we will have about one week in which to prepare ourselves for Armageddon.

To do nothing is to behave like ostriches with our heads in the sand, blindly believing that "everything will be okay" as our world inexorably drifts towards the next naturally recurring, 100-per-cent inevitable, solar superstorm and resultant extreme GMD—which, in short order, will end the industrialised world as we know it, incurring almost incalculable suffering, death and environmental destruction on a scale not seen since the extinction of the dinosaurs some 65 million years ago.

The End of the Grid As We Know It

There are records from the 1850s to today of roughly 100 significant geomagnetic storms, two of which in the last 25 years were strong enough to cause millions of dollars' worth of damage to key components that keep our modern grid powered. In March 1989, a severe GMD induced powerful electric currents in grid wiring that fried a main power transformer in the Hydro-Québec system in Canada, causing a cascading grid failure that knocked out power to six million customers for nine hours. The GMD also damaged similar transformers in New Jersey and the United Kingdom. More recently, in October 2003, a GMD of lesser intensity but greater duration caused a blackout in Sweden and induced powerful currents in the South African grid that badly damaged or destroyed 14 major power transformers, severely impairing commerce and comfort over large

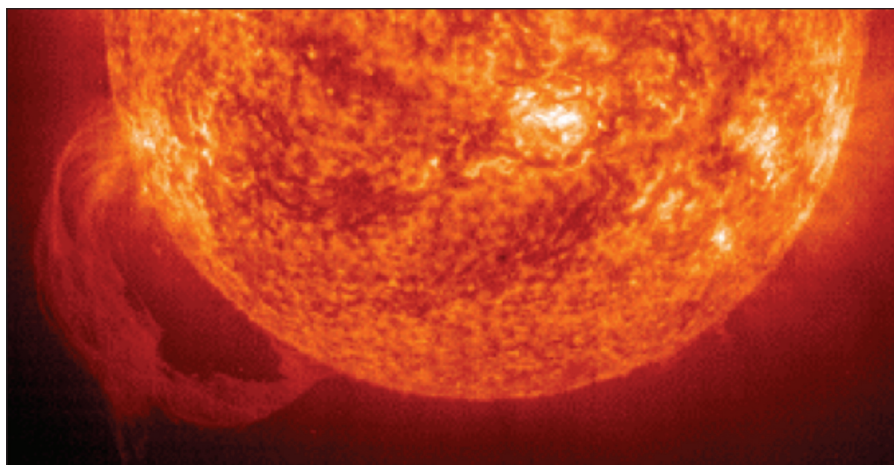
portions of that country as the regulators and utilities were forced to resort to massive rolling blackouts that dragged on for many months.²

On 14–15 May 1921, an extreme GMD produced ground currents roughly 10 times as strong as the 1989 Quebec incident, affecting the northern hemisphere as far south as Mexico and Puerto Rico and the southern hemisphere as far north as Samoa.³

However, the great-granddaddy of GMDs in recorded history is the 1859 Carrington Event. During this geomagnetic storm, which lasted from 28 August to 4 September, the northern lights were seen as far south as Cuba and Hawaii. The GMD induced currents so powerful that telegraph lines, towers and stations caught on fire at numerous locations around the world. The best estimates are that the Carrington Event was roughly 50 per cent stronger than the 1921 incident.⁴

In a detailed study conducted under the auspices of

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Solar coronal mass ejection (CME) (SOHO image, 9 June 2002)

the Electromagnetic Pulse Commission and the Federal Emergency Management Agency, and reviewed in depth by the Oak Ridge National Laboratory and the National Academy of Sciences, Metatech Corporation undertook extensive modelling and analysis of the potential effects of extreme geomagnetic storms upon the US electrical power grid. Metatech based its modelling on a storm approximately 10 times stronger than the 1989 Hydro-Québec event, roughly equivalent to the May 1921 extreme GMD.⁵ Metatech showed how a GMD of this magnitude would induce massive current and voltage spikes into thousands of miles of antenna-like power lines that interconnect the US electric power grid. Metatech estimated that within the continental United States alone, these voltage and current spikes combined with induced harmonic anomalies would severely damage or destroy over 350 extra-high-voltage (EHV) power transformers critical to the functioning of the US grid and possibly well over 2,000 EHV transformers worldwide.

EHV transformers are custom designed for each installation and are made to order, weighing as much as 300 tonnes and costing well over US\$1 million each. Given that there is currently a three-year waiting list for a single EHV transformer (due to increased demand from China and India, the lead times have grown from one to three years) and that the total global

manufacturing capacity is roughly 100 EHV transformers per year when the world's manufacturing centres are functioning properly, you can begin to grasp the serious implications of this situation.

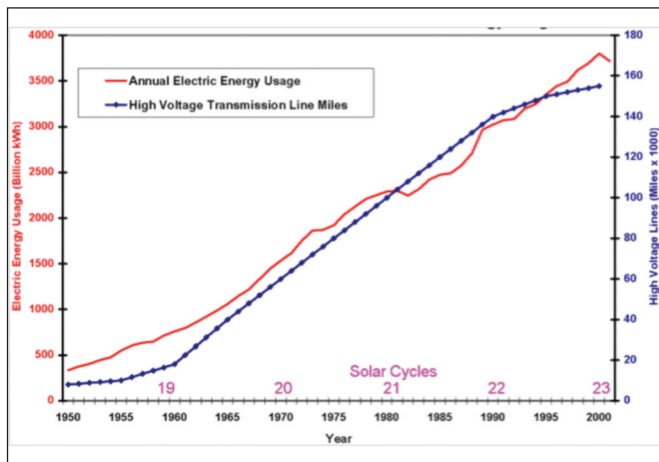
It turns out that the EHV transformers in combination with the hundreds of thousands of miles of high-voltage power lines, which act as giant antennas for capturing EMP- and GMD-induced current and voltage effects, are especially vulnerable to large geomagnetic disturbances. The loss of thousands of EHV transformers worldwide will cause a catastrophic collapse of the grid, stretching across much of the industrialised world. It will take years at best for the industrialised world to put itself back together after such an event, especially considering the fact that most of the manufacturing centres that make this equipment will also be grappling with widespread

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grid failure. Since the Earth's magnetic field tends to protect the tropical latitudes from the most damaging geomagnetic effects, with protection dropping as one travels closer to the poles, perhaps the infrastructure and manufacturing zones in places like Mexico, Malaysia, India and Singapore will be spared, but most of those countries probably also rely on goods and services imported from other parts of the world that will be crippled for many months (or years) in the event of an extreme GMD.

According to the various Metatech analyses, it is estimated that grid collapse will affect at least 130 million people in the United States alone. However, in a recent personal conversation, John Kappenman, author of the Metatech study, admitted that this estimate is probably grossly optimistic. He noted that "killer trees" and other seemingly insignificant events have been attributed to being the tiny seeds that sprouted into gigantic multi-state blackouts. The massive Western States Blackout of 10 August 1996 apparently started when sagging power lines shorted against improperly pruned trees in Oregon during a triple-digit heat wave, cutting power to seven western states and parts of Baja, Mexico, and two Canadian provinces. Due to excessive loads from millions of air-conditioning units operating during the heat wave, the grid had been operating near peak capacity and the shorted lines threw it over the edge into cascading failure, affecting millions of customers.⁷ Again, improperly pruned "killer trees" were apparently the root cause of the 14 August 2003 Great Northeastern Blackout that cut power to over 50 million people.⁸

Kappenman also cited the 8–9 September 2011 event where a utility technician flipped a switch to bypass a



Growth of the US High Voltage Transmission Network and the Annual Electric Energy Usage over the Past 50 Years. In addition to increasing total network size, the network has grown in complexity with the introduction of higher-kilovolt-rated lines that subsequently also tend to carry larger GIC (geomagnetically induced current) flows. (Grid size derived from data in the *EHV Transmission Line Reference Book* and the NERC Electricity Supply and Demand database; energy usage statistics from the US Department of Energy – Energy Information Administration.)⁶

large series capacitor that was not working properly at a substation outside of Yuma, Arizona, and for reasons not fully understood this caused a chain of events leading to a massive cascading blackout that cut power to millions of customers in Arizona, California and Mexico. This same blackout also caused two reactors at the San Onofre nuclear power plant to shut down automatically and go off line, which they are designed to do as a safety precaution in the event of a local grid failure. This exacerbated the situation by reducing the locally available generating capacity at the same time as utility workers were trying desperately to restore power to San Diego and other areas.⁹

The Nuclear “Achilles Heel”

So, what do extended grid blackouts have to do with potential nuclear catastrophes? Nuclear power plants are designed to disconnect automatically from the grid in the event of a power failure, and once disconnected they begin the process of shutting down the reactor's core. In the event of the loss of coolant flow to an active nuclear reactor's core, the reactor will start to melt down and fail catastrophically within a matter of a few hours at most. In an extreme GMD, nearly every reactor in the world could be affected.

It was a short-term cooling system failure that caused the partial reactor core meltdown in March 1979 at Three Mile Island, Pennsylvania. Similarly, according to officials it was not direct damage from Japan's 9.0 magnitude Tohoku earthquake on 11 March 2011 that caused the Fukushima Daiichi nuclear

reactor disaster but the loss of electric power to the cooling system pumps when the facility's massive back-up diesel generators were wiped out by the ensuing tidal waves. In the hours and days after the tidal waves shuttered the cooling system, the cores of reactors nos 1, 2 and 3 were in full meltdown and released hydrogen gas, fuelling explosions which breached several containment vessels.

Of even greater danger and concern than nuclear reactor cores themselves are the spent fuel rods stored in on-site cooling ponds. So-called “temporary” nuclear fuel containment ponds are features common to nearly all nuclear reactor facilities and typically contain the spent fuel from 10 or more decommissioned reactor cores. These fuel containment ponds are generally surrounded by common industrial-type buildings with concrete walls and corrugated steel roofs. Unlike the

active reactor cores which are encased inside massive “containment vessels” with thick walls of concrete and steel, the buildings surrounding spent fuel rod storage ponds will do practically nothing to contain radioactive contaminants in the event of prolonged cooling system failures. Since spent fuel ponds typically hold far greater quantities of highly radioactive material than the active nuclear reactors locked inside reinforced containment vessels, they clearly present far greater potential for the catastrophic spread of highly radioactive contaminants over huge swaths of land, polluting the environment for multiple generations spanning hundreds of years.

A study by the NRC determined that the “boil-down time” for spent fuel rod containment ponds runs from between four and 22 days after loss of cooling system power before degenerating into a Fukushima-like situation, depending upon the type of nuclear reactor and how recently its latest batch of fuel rods were decommissioned.¹⁰

A few days after the tidal waves destroyed the generators providing back-up electrical power to Fukushima Daiichi's cooling system, the protective water bath boiled away from the spent fuel pond for reactor no. 4, leaving the stored spent fuel rods partially exposed to the air. Had it not been for heroic efforts on the part of Japan's nuclear workers to replenish water in this spent fuel pool, these spent rods would have melted down and their zirconium cladding would have ignited, which most likely would have released far more

radioactive contamination than what came from the three reactor core meltdowns.

Japanese officials estimate that, to date, the Fukushima Daiichi nuclear disaster has released just over half of the total radioactive contamination released from Chernobyl, but other sources suggest that the radiation released could be significantly more.

In the event of an extreme GMD-induced long-term grid collapse covering much of the globe, if just half of the world's spent fuel ponds boil off their water and become radioactive zirconium-fed infernos, the ensuing contamination will far exceed the cumulative effect of 400 Chernobyls.

Most of us tend to believe that a nuclear reactor is something that can be shut down in short order, like some massive piece of machinery that can be turned off by simply flipping a switch or performing a series of

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operations in a prescribed manner over a relatively short time, such as a few hours or perhaps a day or two. In spite of my MIT education (BSME, 1978), until recently I, too, was under the spell of this comforting delusion which is far from the truth.

You see, the trillions of chain reactions going on inside a nuclear reactor's core continuously produce such incredible amounts of energy that a single nuclear power plant can generate more electricity than is required to power a good-sized city. Unfortunately, these reactions do not simply "cease fire" at the flip of a switch. In general, it takes over 5–7 days to slow down a reactor core's nuclear chain reactions to the point where the core may be removed from the reactor. After removal, the fuel rods are quite "hot" in terms of both temperature and radioactivity. For the next 3–5 years, these fuel rods must be immersed under many feet of continuously cooled water in order to shield the surrounding area from a high level of radioactivity as well as to prevent catastrophic meltdown from occurring.

According to nuclear whistleblower Arnie Gundersen, former Senior Vice President with Nuclear Engineering Services Corporation, after slowing down the chain reactions inside the reactors' cores at Fukushima for a full eight months, the fuel rods would start melting down again if coolant flow were suspended for just 38 hours. Arnie explained that, essentially, all modern nuclear reactors are designed with banks of "fuel rods", which contain highly radioactive materials, combined with banks of "control rods", which mesh between the fuel rods like the interwoven fingers of your right and left hands. It is the degree of interweave that moderates and controls the rate of nuclear chain reactions. He further explained that in the event of a significant loss of reactor control, reactors are designed for a "fail-safe" process to occur, where the control rods automatically fall into the fully meshed position with respect to the fuel rods, resulting in maximal slowing of the core's nuclear reactions and beginning the process of shutting down the reactor.¹¹

Typically, this action rapidly reduces the power produced by these chain reactions by a factor of 20:1 (to 5.0 per cent of full power), but that still leaves millions of horsepower worth of waste heat that must be removed if the reactor core is not to overheat and fail catastrophically. After a day of leaving the control rods in the fully interwoven position, this reaction slows to 1.0 per cent, and after a week it will be about 0.1 per cent of full power. Once the reactions in the fuel rods slow to the point where the rods may be removed from the reactor, the spent fuel rods must be cooled inside

containment ponds for 3–5 more years before the nuclear reactions reach a point where the rods can be moved to specially designed air-cooled storage banks.

As mentioned previously, nuclear power plants are only required to store enough fuel reserves on site to keep their back-up diesel generators running for one week. The NRC has always operated on the assumption that extended grid "blackouts" will not last for more than a few days. The government has promised that, in the event of a major catastrophe such as a hurricane Katrina, diesel trucks will show up like clockwork at all troubled nuclear facilities until local grid-supplied electrical power services are re-established. Unfortunately, governments and regulators do not consider the possibility that the next extreme GMD which Mother Nature unleashes upon Earth will quite likely disrupt grid services over much of the industrialised world for a period of years, not just days. The chances that the world's nuclear reactors will receive weekly deliveries of diesel fuel under such chaotic circumstances are almost zero!

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Electromagnetic Pulse Attacks

Electromagnetic pulses (EMPs) and solar superstorms are two different, but related, categories that are often described as high-impact, low-frequency (HILF) events. HILF events don't happen very often, but if and when they do they have the potential to severely affect many millions of people.

Think of an EMP as a super-powerful radiowave capable of inducing damaging voltage spikes in electrical wires and electronic devices across vast geographical areas. (Note that the geomagnetic effects of solar storms are also described as "natural EMP".)

What is generally referred to as an EMP strike is the result of the deliberate detonation of a nuclear device at high altitude, roughly defined as somewhere between 24 and 240 miles (~38.6 and 386.4 kilometres) above the surface of the Earth.

Nuclear detonations of this type have the potential to cause serious damage to electronics and electrical power grids along their line of sight, covering huge distances in the order of a circular area 1,500 miles (2,415 km) in diameter, which would correspond to an area stretching roughly from Quebec City in Canada down to Dallas, Texas.

The concern is that some rogue state or terrorist organisation might build their own nuclear device from scratch or buy one illegally, procure a Scud missile on the black market and launch their nuclear device from a large fishing boat or freighter somewhere off the coast of the United States, causing grid collapse and widespread damage to electronic devices across roughly

50 per cent of America. Much like an extreme GMD, a powerful EMP attack would cause widespread grid collapse, although this would be limited to a much smaller geographical area.¹²

A powerful EMP from a suborbital nuclear detonation would cause extreme electromagnetic effects, starting with an initial short duration "speed of light" pulse, referred to as an E1 effect, followed by a middle-duration pulse called an E2 effect, followed by a longer-duration disturbance known as an E3 effect. The E1 effect is particularly damaging to modern electronic equipment, especially digital micro-electronics. The intermediate E2 effect is similar to many thousands of lightning strikes hitting over a widespread area at almost exactly the same time. In the case of a nuclear-induced EMP, its E3 effect starts after about half a second and may continue for several minutes. Electromagnetically, it is quite similar to the effect from an extreme GMD, except the latter may continue for a number of hours or days.

A "successful" EMP attack launched against the US would most likely result in the immediate collapse of the grid across roughly 50 per cent of the country, the crash of the stock market and the destruction of many of the critical digital electronic systems located in the affected areas that control nuclear reactors, chemical plants, telecommunications systems and industrial processes. Modern digital electrical systems, absolutely critical for running factories, refineries, power plants, sewage plants, etc., are highly susceptible to EMP damage. These systems include programmable logic controllers (PLC), digital control systems (DCS) and supervisory control and data acquisition (SCADA).

Bill Kaewert, President and CTO of Stored Energy Systems, LLC, a supplier of back-up power systems and components for mission-critical structures such as Minuteman III missile silos, data centres and corporate facilities, recently took part in a "tabletop EMP" exercise at the National Defense University. Dozens of the nation's leading first responders, public safety experts and military personnel took part in this exercise that simulated a massive grid-down scenario typical of an EMP attack or an extreme GMD. According to Kaewert, even these highly trained personnel had a hard time grappling with the public safety implications of a disaster the size of 50 hurricane Katrinas. It was also quite apparent that in an extended grid collapse, a large number of emergency responders, military and government personnel would abandon their posts to protect their family and friends from the ensuing chaos.¹³

The only good news about an EMP strike is that its effect will cover a much smaller area than will an extreme GMD, so there will be a significant portion of the rest of the US, as well as the rest of the outside world, left intact and able to lend a hand towards rebuilding critical infrastructure in the affected areas. Imagine the near total loss of functioning infrastructure across an area of about a million square miles (~1.61 million sq. km; equivalent to 50 hurricane Katrinas happening simultaneously) and you will have some idea of the crippling effect of an EMP attack from a single suborbital nuclear detonation!

Preventing Armageddon

The Electromagnetic Pulse Commission has studied the threat of both EMP and extreme GMD events and made recommendations to US Congress to take a series of active steps to ensure the survival of the grid and other critical infrastructure.

John Kappenman of Metatech estimates that it would cost in the order of US\$1 billion to build special protective devices into the US grid to protect the EHV transformers from EMP or extreme GMD damage and to build stores of critical replacement parts should some of these items be damaged or destroyed. He estimates that it would cost significantly less than \$1 billion to store at least a year's worth of diesel fuel for

back-up generators at each US nuclear facility and to store sets of critical spare parts, such as back-up generators, inside EMP-hardened steel containers to be available for quick change-out should a generator be damaged by an EMP strike and fail to start.¹⁴

To me, this is a no-brainer. For the cost of a single B-2 bomber or a tiny fraction of the TARP bank bailout, we could invest in pro-active preventive measures to avert what might well become the end of our civilisation and life as we know it! There is no way to protect against all possible effects from a solar superstorm, an extreme GMD or an EMP attack, but certainly we could implement measures to protect against the worst effects. Since 2008, Congress has narrowly failed to pass legislation that would implement the EMP Commission's recommendations.¹⁵ We have a long way to go to make our world EMP safe, but every citizen can do their part to push for legislation to move towards this goal and work inside their home and community to develop more local resilience and self-reliance so that, in the event of a longer-term grid-down scenario, they might make the most of a bad situation. ∞

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