<https://www.domesticpreparedness.com/commentary/electromagnetic-pulses-six-common-misconceptions/>,

**It is not cost prohibited to protect the Grid - a Misconception #4**

by George H. Baker Wed, November 05, 2014

Many misconceptions about electromagnetic pulse (EMP) effects have circulated for years among technical and policy experts, in press reports, on preparedness websites, and even in technical journals. Because many aspects of EMP-generation physics and its effects are obscure, misconceptions from those who do not perceive the seriousness of the effects to those who predict a doomsday chain of events are inevitable. However, not all EMPs are the same, with the most significant effects being caused by E1 and E3 fields.

Nuclear bursts detonated at altitudes above 40 km generate two principal types of EMPs that can debilitate critical infrastructure systems over large regions:

* The first, a “fast-pulse” EMP field, also referred to as E1, is created by gamma ray interaction with stratospheric air molecules. The resulting electric field peaks at tens of kilovolts per meter in a few nanoseconds, and lasts a few hundred nanoseconds. E1’s broadband power spectrum (frequency content from DC to 1 GHz) enables it to couple to electrical and electronic systems in general, regardless of the length of their cables and antenna lines. Induced currents range into the thousands of amperes and exposed systems may be upset or permanently damaged.
* The second “slow-pulse” phenomenon, is referred to as magnetohydrodynamic (MHD) EMP, or E3, and is caused by the distortion of Earth’s magnetic field lines due to the expanding nuclear fireball and the rising of heated, ionized layers of the ionosphere. The change of the magnetic field at the Earth’s surface induces a field in the tens of volts per kilometer, which, in turn, induces low-frequency currents of hundreds to thousands of amperes in long conducting lines only (a few kilometers or longer) that damage components of long-line systems, including the electric power grid and long-haul communication and data networks.

By over- and under-emphasizing realistic consequences of EMPs, policymakers may delay actions or dismiss arguments altogether. The six misconceptions about EMPs that are perhaps the most harmful involve: (a) exposed electronic systems; (b) critical infrastructure systems; (c) nuclear weapons; (d) cost of protection; (e) type of EMPs; and (f) fiber-optic networks.

**Misconception 1**: EMP Will Cause Every Exposed Electronic System to Cease Functioning.

Based on the U.S. Department of Defense (DOD) and Congressional EMP Commission’s EMP test databases, small, self-contained systems, such as motor vehicles, hand-held radios, and unconnected portable generators, tend not to be affected by EMPs. If there is an effect on these systems, it is often temporary upset rather than component burnout.

On the other hand, threat-level EMP testing also reveals that systems connected to power lines are highly vulnerable to component damage requiring repair or replacement. Because the strength of EMP fields is measured in volts per meter, the longer the conducting line, the more EMP energy will be coupled into the system, and the higher the probability of damage. As such, the electric power-grid network and landline communication systems are almost certain to experience component damage when exposed to an EMP with cascading effects to most other (dependent) infrastructure systems.

**Misconception 2**: EMP Effects Will Have Limited, Easily Recoverable, “Nuisance” Effects on Critical Infrastructure Systems. - Although an EMP would not affect every system, widespread failure of a significant fraction of electrical and electronic systems will cause large-scale cascading failures of critical infrastructure networks because interdependencies among affected and unaffected systems. Mathematician Paul Erdos’s “small-world” network theory applies, which refers to most nodes – equipment attached to a network – being accessible to all others through just a few connections. The fraction of all nodes changes suddenly when the average number of links per single network connection exceeds one. For example, a single component failure, where the average links per node is two, can affect approximately half of the remaining “untouched” network nodes.

For many systems, especially unmanned systems, loss of control is tantamount to permanent damage, in some cases causing machinery to self-destruct. Examples include:

* Lockup, or not being able to change the “on” or “off” state, of long-haul communication repeaters;
* Loss of remote pipeline pressure control in supervisory control and data acquisition (SCADA) systems, which communicate with remote equipment;
* Loss of generator controls in electric power plants; and
* Loss of machine process controllers in manufacturing plants.

**Misconception 3**: Megaton- Nuclear Weapons Are Required to Cause Serious EMP Effects.

Due to a limiting atmospheric saturation effect in the EMP-generation process, low-yield weapons produce a peak E1 field similar in magnitude to high-yield weapons if they are detonated at altitudes of 50-80 km. The advantage of high-yield weapons is that their range on the ground is affected less significantly when detonated at higher altitudes.

Nuclear weapons with yields ranging from 3 kilotons to 3 megatons (a 3 order of magnitude difference in yield), when detonated at their optimum burst altitudes, exhibit a range of peak E1 fields on the ground differing by only a factor of ~3, viz. 15-50 KV/meter. With respect to the late-time (E3, or low-amplitude, low-frequency components) EMP field, a 30-KT nuclear weapon above 100 km would cause geomagnetic disturbances as large as solar superstorms, although over smaller regions. It also is worth noting that peak currents on long overhead lines induced by E1 from 10 kiloton- weapons can range in the kiloamperes with voltages reaching into the hundreds of kilovolts.

**\*\* Misconception 4**: Protecting the Critical National Infrastructure *Would Be Cost Prohibitive.*

Of the 14 critical infrastructure sectors, EMP risk is highest for electric power grids and telecommunication grids because of their network connections and criticality to the operation and recovery of other critical infrastructure sectors. Attention to hardening these infrastructure grids alone would provide significant benefits to national resilience.

The electric power grid is essential for sustaining population “life-support” services. However, some major grid components could take months, or years, to replace if many components are damaged. The primary example is high-voltage transformers, which can irreparably fail during major solar storms and are thus likely to fail during an EMP event. Protection of these large transformers would reduce the time required to restore the grid and restore the necessary services it enables.

According to Emprimus, a manufacturer of transformer protection devices, the unit cost for high-voltage transformer protection is estimated to be [$250,000](http://tcbmag.com/Industries/Technology/Can-Emprimus-Save-Civilization), with the total number of susceptible large, high-voltage units ranging from 300 to 3,000, according to Oak Ridge National Laboratory. The requirement and cost for generator facility protection are still undetermined but are likely to be similar to transformer protection costs. To protect SCADA systems, replacement parts are readily available and repairs are relatively uncomplicated. Protection costs for heavy-duty grid components are in the $10 billion range, which is a small fraction of the value of losses should they fail. When amortized, protection costs to consumers amount to pennies per month.

**Misconception 5**: Only Late-Time EMP (E3) Will Damage Electric Power-Grid Transformers.

Oak Ridge National Laboratory’s [January 2010 report](http://web.ornl.gov/sci/ees/etsd/pes/pubs/ferc_Meta-R-320.pdf) on its E1 tests of 7.2-KV distribution transformers produced permanent damage to transformer windings in seven of the 20 units tested. The failures were due to transformer winding damage caused by electrical breakdown across internal wire insulation. As an important side note, transformers with direct-mounted lightning surge arrestors were not damaged during the tests. Similar tests of high-voltage transformers are needed.

**Misconception 6**: Fiber-Optic Networks Are Not Susceptible to EMP Effects.

In general, fiber-optic networks are **less** susceptible than metallic line networks; however, fiber-optic multipoint *line driver and receiver boxes*, which are designed to protect against ground current, may fail in EMP environments. Long-haul telecommunication and regional Internet fiber-optic repeater amplifiers’ *power supplies are particularly vulnerable* to EMP environments (Figure 1). Terrestrial fiber-optic cable repeater amplifier power is provided by the electric power grid and thus vulnerable to grid failure as well as to direct EMP/E1 effects.

Undersea cable repeater amplifiers also are vulnerable to EMP/E3 effects since they are connected to a coaxial metallic power conductor that runs the length of the line. Because of its low-frequency content, E3 penetrates to great ocean depths, which subjects undersea power amplifiers to high risk of burnout. On the positive side, line drivers/receivers and repeater amplifiers are relatively easy to protect using shielding, shield-penetration treatment, and power-line filters and/or breakers.

Standardized Solutions

From a [risk-based priority](http://works.bepress.com/cgi/viewcontent.cgi?article=1041&context=george_h_baker) standpoint, the electric power grid is a high priority for EMP protection. Hardening this infrastructure alone would have major benefits for national resilience – the ability to sustain, reconstitute, and restart critical services. EMP engineering solutions have been implemented and standardized by DOD since the 1960s and are well documented:

* MIL-STD-188-125-1 – “DOD Interface Standard – High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions – Part 1 – Fixed Facilities” (17 July 1998);
* MIL-STD-188-125-2 – “DOD Interface Standard – High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions – Part 1 – Transportable Systems” (3 March 1999); and
* MIL-HDBK-423 – “Military Handbook – High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based C4I Facilities Vol. 1 – Fixed Facilities” (15 May 1993).

With respect to the power grid, the installation of blocking devices in the neutral-to-ground conductors of large electric distribution transformers will significantly reduce the probability of damage from slow EMP/E3. Transformer protection against E1 overvoltages is achievable by installing common metal-oxide varistors (control elements in electrical circuits) on transformers from each phase to ground. Costs for protecting the power grid are small compared to the value of the systems and services at risk.

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