Presenter: Mike Caruso
Consultant-EMP Specialist
Relay & Power Systems
Agenda

- Terminology
- Legislation & Specifications
- EMP Threat
- Current Control Houses
- Future Control Houses
- System Design
- System Verification
- Conclusions
High Power Electromagnetics (HPEM) used in the IEEE EMC Society for many years to define:

- EM fields from nearby lightning ground strikes (LEMP)
- EM fields near an electrostatic discharge (ESD)
- EM fields from radars at airports or at navy facilities (HIRF)
- EM fields from switching events in high voltage substations
- Electromagnetic pulse (EMP) fields from nuclear bursts
- Intentional electromagnetic interference (IEMI) environments
Terminology

Electromagnetic Pulse (EMP)
• An umbrella term identifying damaging two forms of high power electromagnetic signals

High-altitude Electromagnetic Pulse (HEMP)
• Damaging electromagnetic signals (>50,000 volts/meter) emitted from a nuclear detonation in outer space at any altitude above 18 miles (30 km)
  • Note: No damaging near field or radiation effects

Intentional Electromagnetic Interference (IEMI)
• Disruptive and data altering electromagnetic signals caused by the malicious use of electromagnetic weapons (non-detonation, within targeted footprints)
Geomagnetic Storm (GS)

- A geomagnetic storm is **completely distinct from EMP** a temporary disturbance of the Earth's magnetosphere caused by a solar wind shock wave and/or cloud of magnetic field which interacts with the Earth's magnetic field.

Coronal Mass Ejection (CME)

- Geomagnetic storm is due to a solar coronal mass ejection (CME) or a high speed stream of the solar wind, containing magnetic particles, originating from a region of weak magnetic field on the Sun’s surface.
Geomagnetically Induced Currents (GIC)

- Geomagnetically induced DC currents (GIC), that can couple onto power lines and cause saturation in EHV transformers.
- In 1989, a geomagnetic storm energized ground induced currents which disrupted electric power distribution throughout most of the province of Quebec and caused aurorae as far south as Texas.

Second Order Harmonics (120Hz)

- As a result of EHV transformers going into saturation they will produce second order harmonics that can damage SCADA Systems and related control equipment.
Terminology

Waveform

Time (s)

E(t)/V/m

Lightning Field @ 10 meters

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**Terminology**

- **IEMI**
**Terminology** (Critical Infrastructure)

- Nuclear Reactors, Materials, & Waste Sector
- Chemical Sector
- Commercial Facilities Sector
- Critical Manufacturing Sector
- Dams Sector
- Transportation Systems Sector
- Food and Agriculture Sector
- Information Technology Sector
- Financial Services Sector
- Government Facilities Sector
- Emergency Services Sector
- Healthcare and Public Health Sector
- Water and Wastewater Systems Sector
- Communications Sector
- Defense Industrial Base Sector
- Energy Sector (electricity, petroleum, and natural gas)

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U.S. Congress:

- June 25, 2015 Passed Committee on Homeland Security
- S. 1846 Critical Infrastructure Protection Act of 2015
- As ordered reported by the Senate Committee on Homeland Security and Governmental Affairs on July 29, 2015
- S.1846: 11/17/2015 Received in the Senate and Read twice and referred to the Committee on Homeland Security and Governmental Affairs
- S.1846: 5/09/2016 Placed on Senate Legislative Calendar under General Orders. Calendar No. 457
Legislation & Specifications

• December 2, 2016 U.S. House of Representatives passed The National Defense Authorization Act (NDAA) (86%)
• December 8, 2016 U.S. Senate passed The National Defense Authorization Act (NDAA) (92%)
• December 23, 2016 Signed into law by the President
• Section 1913 of NDAA includes: “EMP and GMD Planning, Research and Development, and Protection and Preparedness” (CIPA)
• Section 1913 Amends The Homeland Security Act of 2002
• 180 Days Intelligence Based Review, “A Recommended Strategy to Protect and Prepare the Critical Infrastructure of The Homeland Against Threats of EMP and GMD”
Legislation & Specifications

MIL STD 188-125 1&2
PULSE (HEMP) PROTECTION
HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION FOR GROUND-BASED FACILITIES PERFORMING CRITICAL, TIME-URGENT MISSIONS, PART 1 FIXED FACILITIES

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EMP Protection Level 3 Summary
(where only minutes of mission outage is acceptable):

In addition to level 2, use civil EMP protection standards (like International Electrotechnical Commission (IEC) SC 77C). Use EMP shielded racks/rooms and/or facilities to protect critical computers, data centers, phone switches, industrial and substation controls and other electronics. Shielding should be 30-80 dB of protection thru 10GHz. Use EMP rated surge protection devices (SPDs) to protect equipment outside of shielded areas. Facilities can use single-door EMP-safe entryways. Use International Telecommunication Union (ITU) and IEC EMP standards for design guidance and testing. Have 30 days of back-up power with on-site fuel (or via assured service agreement with EMP resilient refuelers). Use EMP protected HF radio and satellite voice/data nets if organizations need long-range links to support missions. Expedient shield testing can be accomplished using interior scans for FM and AM radio reception and for cell phone signal detection or with the use of IEEE 299. Organizations can also use publicly available IEC SC 77C standards versus military standards for further protection guidance.
EMP Protection Level 4 Summary (where only seconds of mission outage is acceptable):

Use Military EMP Standards (MIL-STD-188-125-1 & MIL-HDBK-423), and 80+ dB hardening thru 10 GHz. Use EMP/RFW shielding in rooms, racks, and/or buildings to protect critical equipment. Use EMP SPDs to protect equipment outside of shielded areas. Use EMP protected double-door entryways. Have 30+ days of supplies & EMP protected back-up power (to include on-site fuel) for critical systems. Don’t rely on commercial Internet, telephone, satellite, or radio nets that are not EMP protected for communications. Use Appendix A for EMP Protection Test and Acceptance Criteria. Use EMP protected fiber, satellite, & radio links & Appendix B services.
### Legislation & Specifications

<table>
<thead>
<tr>
<th>Frequency &amp; Field</th>
<th>MIL-STD-188-125</th>
<th>IEC SC 77C</th>
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</thead>
<tbody>
<tr>
<td>10 GHz Microwave</td>
<td>80 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>1GHz plane wave field</td>
<td>80 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>100MHz plane wave field</td>
<td>80 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>10MHz magnetic field</td>
<td>80 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>1MHz magnetic field</td>
<td>60 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>100KHz magnetic field</td>
<td>40 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
<tr>
<td>14KHz magnetic field</td>
<td>23 dB</td>
<td>30-80 dB Application Dependent</td>
</tr>
</tbody>
</table>

Note: 80 dB of attenuation means that the electric or magnetic field will be reduced by a factor of 10,000 (e.g. 50 kV/m becomes 5V/m).

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EMP Threat

How much EMP is needed to destroy your data equipment?

- Volts per meter (V/m) are the standard units of electric field strength used to determine electromagnetic immunity in products and equipment.
- Most electronic equipment can survive a pulse of 10 Volts per meter.
- An EMP would create a pulse higher than 10,000 V/m.

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EMP Threat

Immunity Standards

• IT Equipment - 10 Volts/meter
• Medical Equipment – 10 Volts/meter
• Network Telephone Equipment – 10 Volts/meter
• Aircraft- (HIRF) 7,200 Volts/meter
• Automobiles – 100 Volts/meter
• Military Equipment – 200 Volts/meter
# EMP Threat

<table>
<thead>
<tr>
<th>System Type</th>
<th>EMP/E3 or GMD Vulnerability</th>
<th>EMP/E1 Vulnerability</th>
<th>RF Weapon Vulnerability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Power Transmission/Distribution</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Electric Power Grid Electronic Control, Monitor Systems</td>
<td>1*</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Long Haul Comm, Data Lines Repeater Systems</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Data Center Equipment Rooms</td>
<td>1*</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>SCADA, Process Control Systems</td>
<td>1*</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Vehicles, Ships, Aircraft Electronics</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Hand-held Electronics</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

*Vulnerable to transformer saturation harmonics

Contributed by Dr. George Baker

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EMP Threat

- Functions of Government, Private and Public Institutions are becoming an increasingly significant component of the Critical Infrastructure sustainability.
- The concern over the effects of HEMP and IEMI on the Electrical Power Grid has grown exponentially as we become more dependent on electronics for survival.
- The need to address HEMP and IEMI protection for Critical Infrastructure Resiliency is being recognized.
- Current Control Center, Data Center and Related Equipment Designs do not address HEMP and IEMI.
EMP Threat

All electronic equipment and apparatus could be destroyed.

• Every device that relies on integrated circuits for operation could be immediately disabled or destroyed.

• Unlike a cyber-attack where “fingerprints” can often be found for forensic analysis, an IEMI attacker will not leave any information behind.

• An EMP shutdown of electronics is so rapid that the log files in computers will not record the event.
EMP Threat

Affected Region vs. Nuclear Burst Altitude

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EMP Threat

Likely Blackout Regions  (Source: Oak Ridge National Laboratory)

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Mobile EM Transmitter

Communication and Data lines

Commercial Power

IEMI Coupling

Network

Window

Metatech

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EMP Threat

Counter-electronics High-powered Advanced Missile Project (CHAMP) by Boeing

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IEMI “Truck Mounted” Weapon

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IEMI “Vehicle Mounted” Weapon
EMP Threat

IEMI “Suitcase” Weapon
EMP Threat

Metcalf Substation, San Jose CA 2013
Current Control Houses

- Brick and Mortar Buildings
- “Legacy” Metal Frame / Metal Siding Buildings
- Pre-manufactured Concrete Modular Buildings

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