# Estimating HEMP Damage for Power Utilities

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# Outline

- PSE Report with Conclusions
- Geomagnetic Storms, 1859
- Ongoing Review of HEMP Science
- Electrical Description of HEMP
- Threat Potential
- Damage Potential
- References

National Academy of Sciences, 2008: 1 in 100 year geomagnetic storm

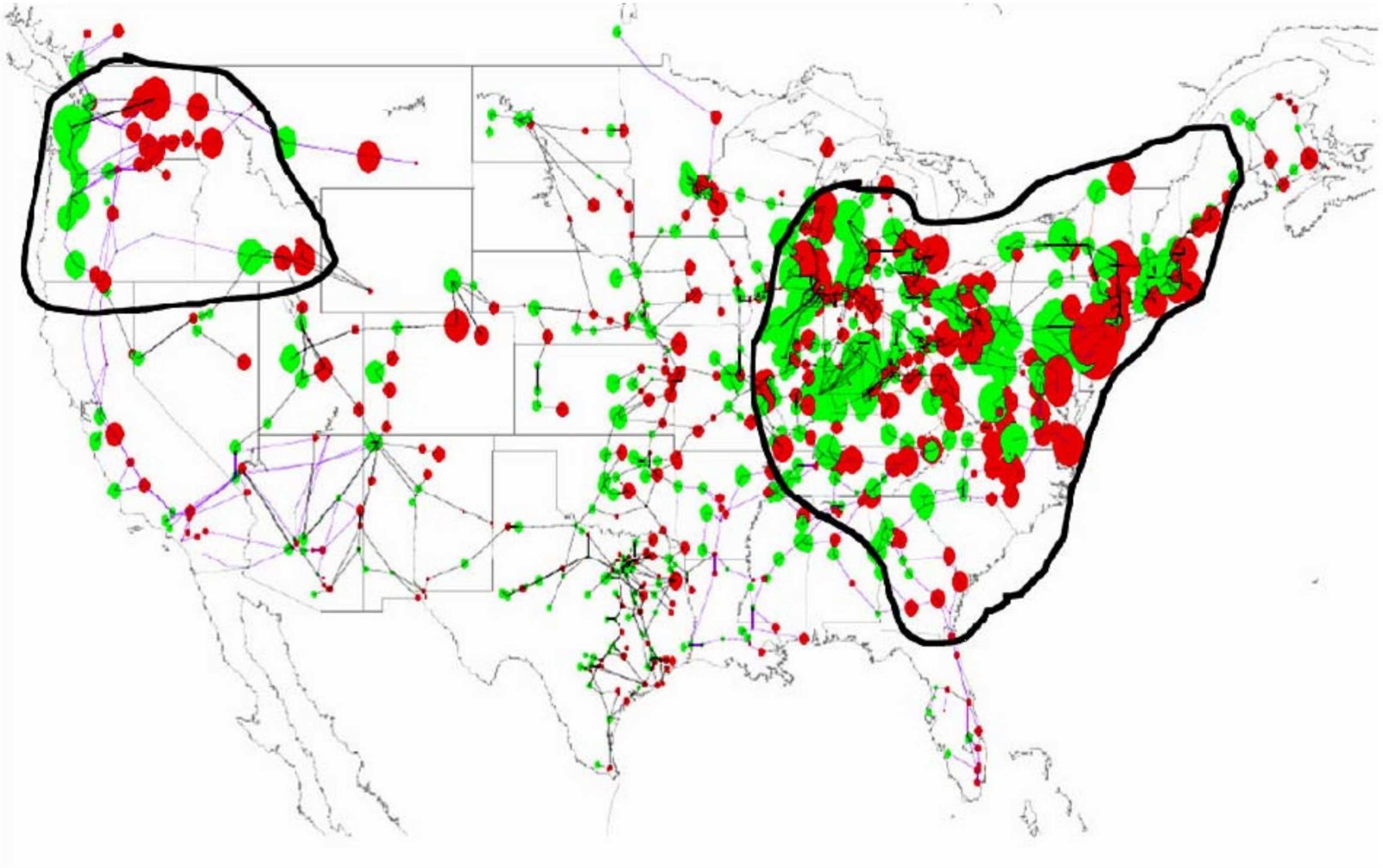


Figure 1. **Areas of Probable Power System Collapse**

MIL-STD-188-125-1 E1

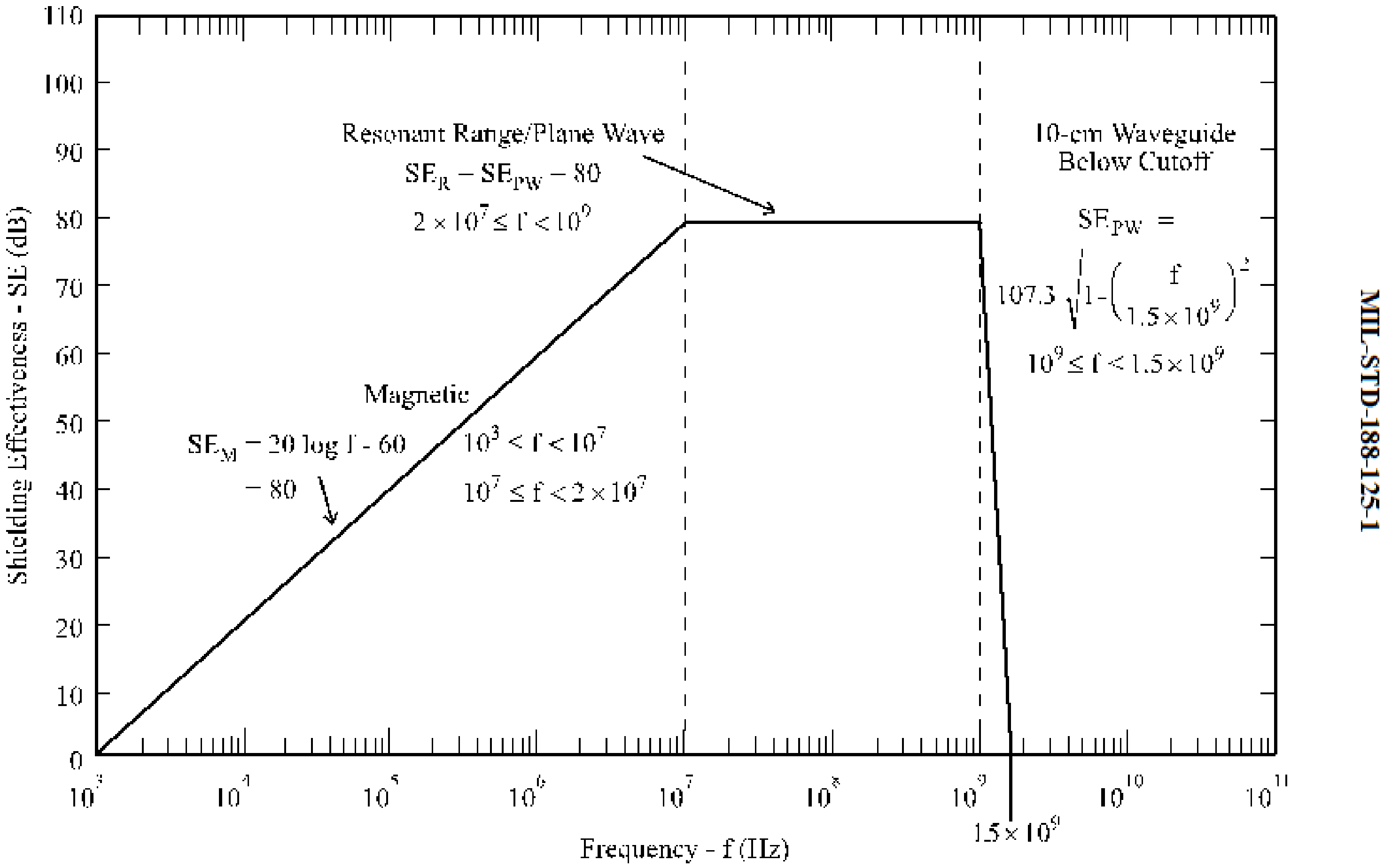



FIGURE 1. Minimum HEMP shielding effectiveness requirements (measured IAW procedures of Appendix A).

ITU-T K.87 (06/2016) E1, E2, E3

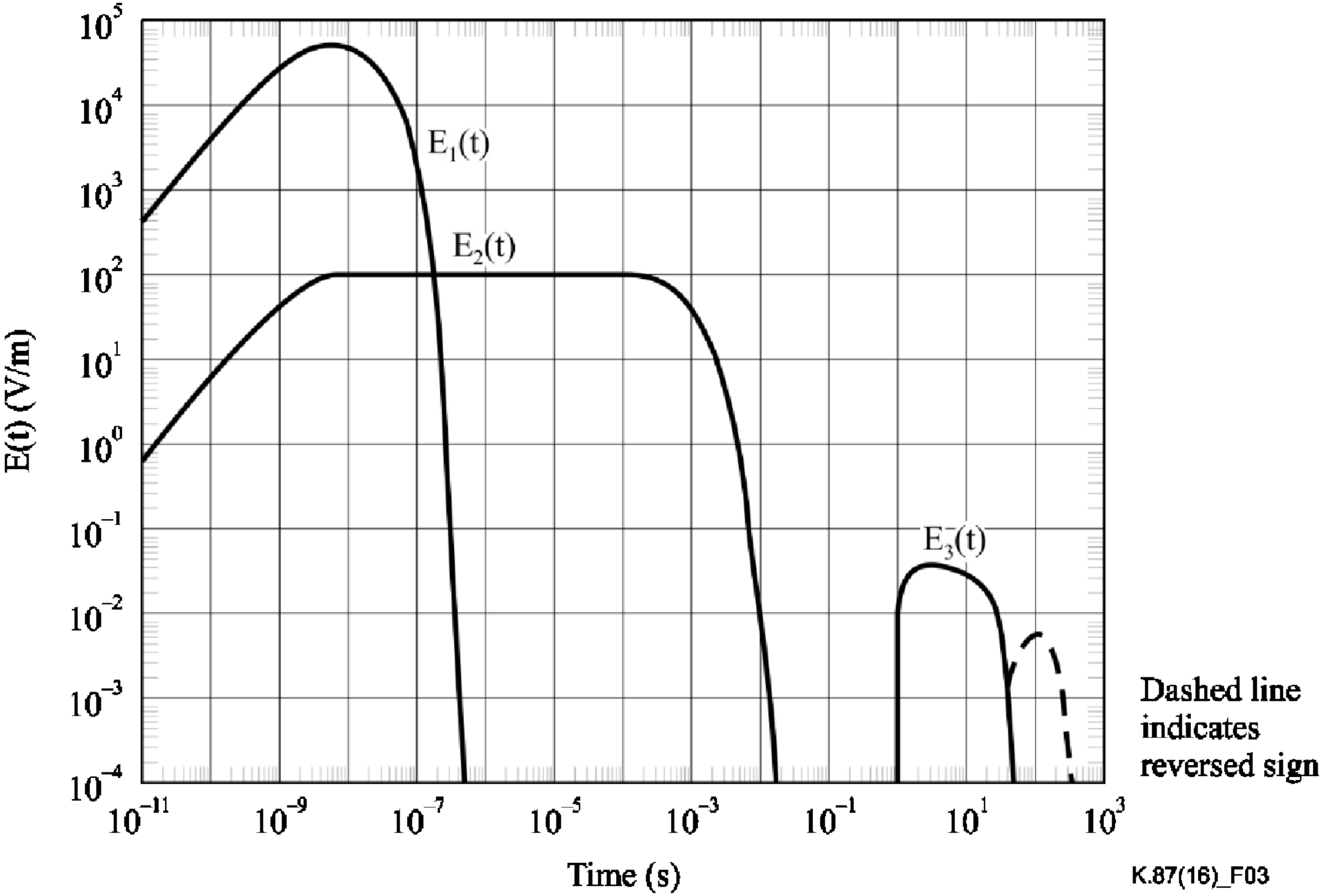
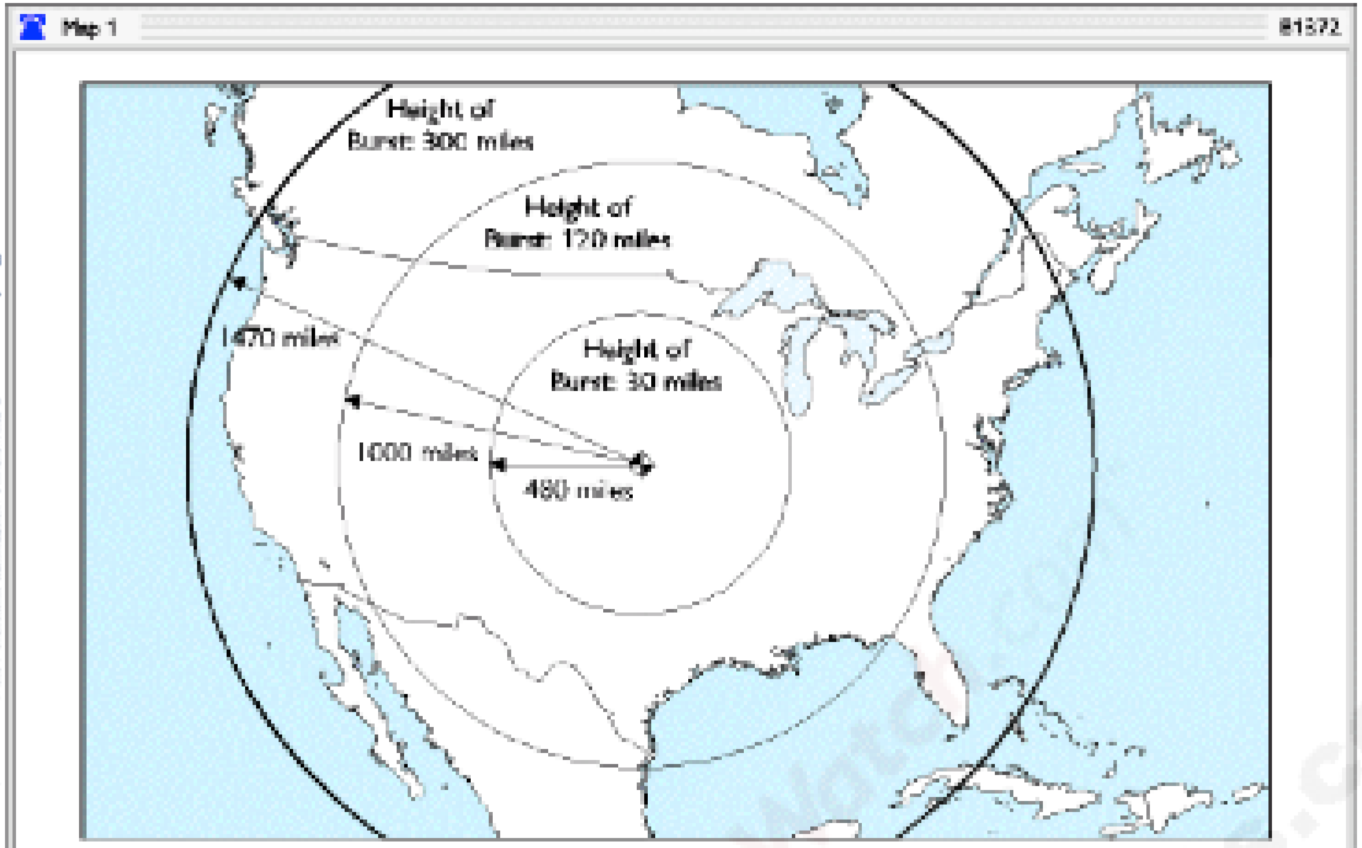



**Figure 3 – Pulse characteristics**

# Extreme Case

**Figure 1. Estimated Area Affected by High-Altitude EMP**

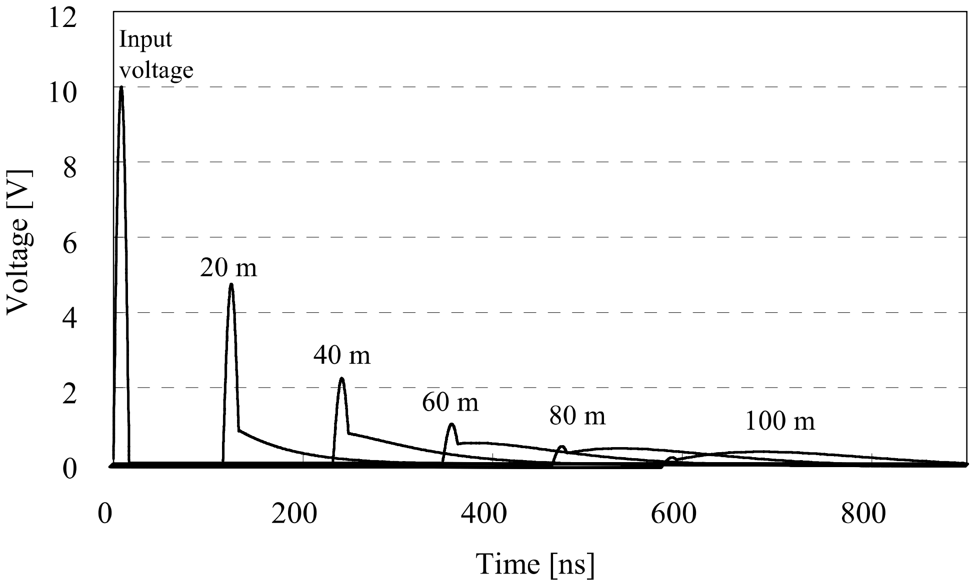



**Area Effected by an Electromagnetic Pulse, by Height of Burst**

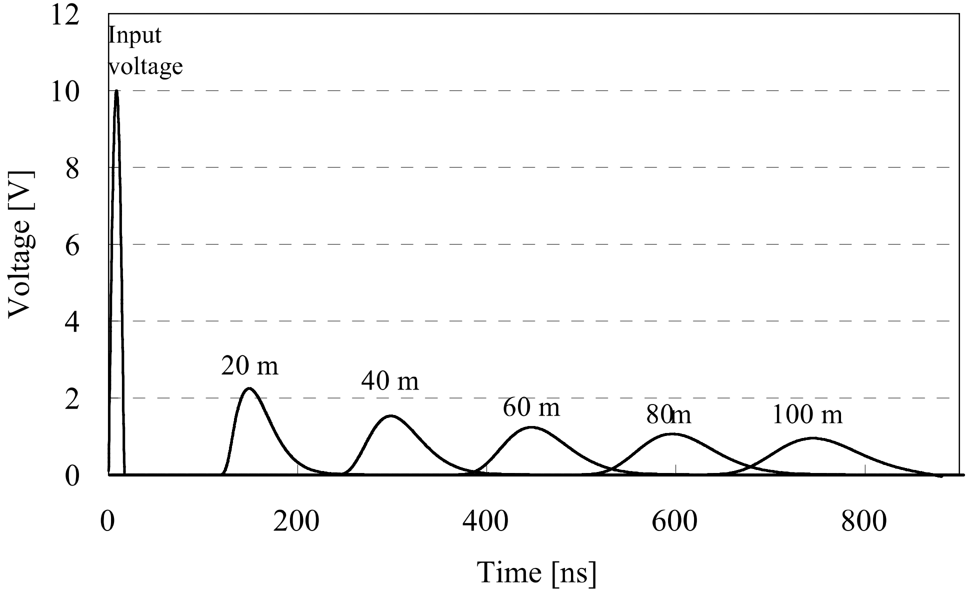
Source: Gary Smith, "Electromagnetic Pulse Threats," testimony before the House National Security Committee, July 16, 1997.

**Source:** Heritage Foundation, Jack Spencer, *America's Vulnerability to a Different Nuclear Threat: An Electromagnetic Pulse*, Backgrounder #1372, May 26, 2000, [http://www.heritage.org/Research/MissileDefense/bg1372.cfm].

# Signal Blurring




(b) $\sigma=10^{-3}$ S/m




(d) $\sigma=10^{3}$ S/m

Zhang Jianguo, Zhang Xin, Xidian University

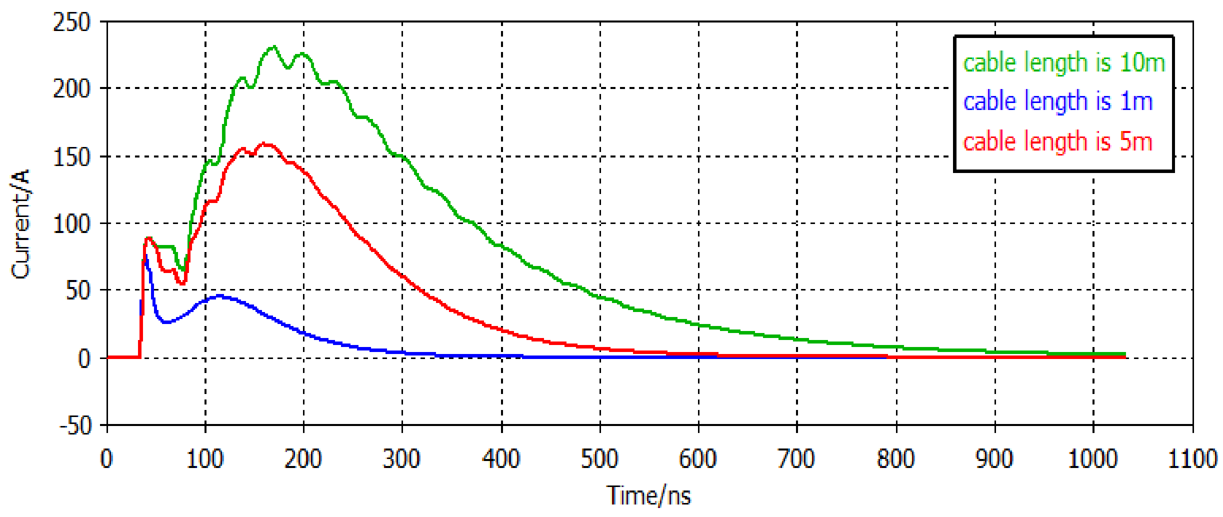



Fig.3 Coupling currents at the port vary with cable length under the HEMP

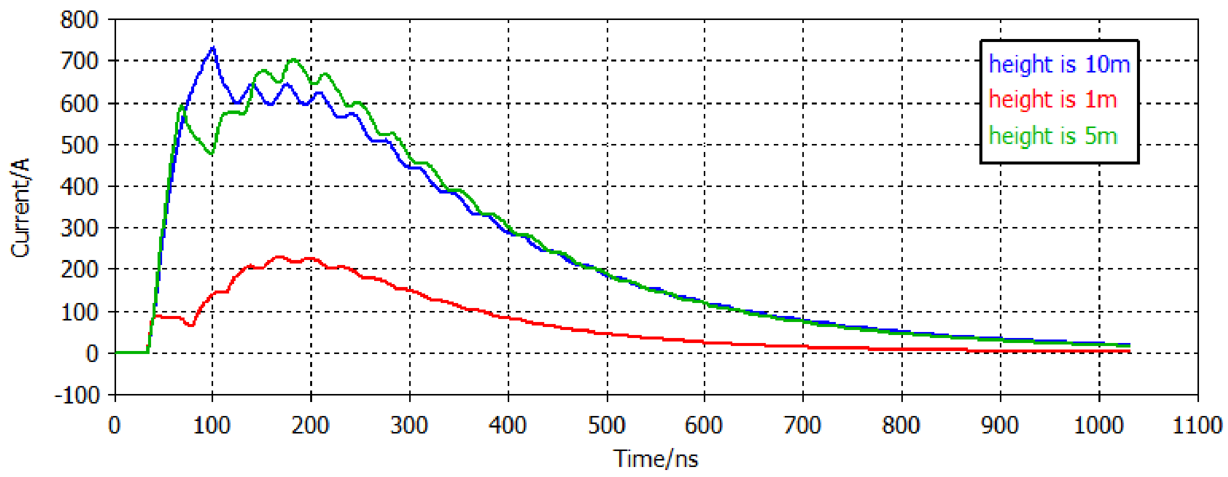



Fig.4 Coupling currents at the port vary with cable height under the HEMP

# Absorption

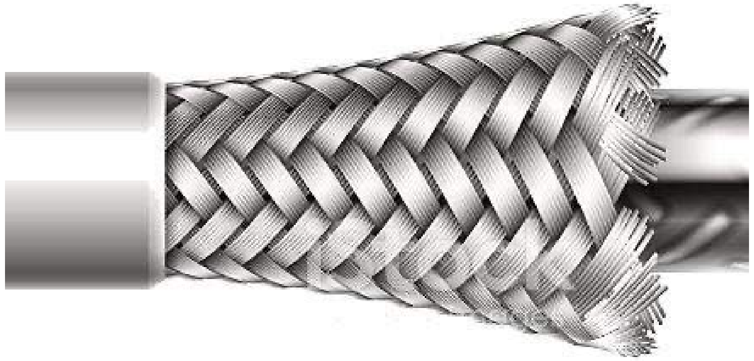


*Fig. 1:* A braided screen of a cable – “French braid”.

The specifications of these two kinds of screens are different, Fig. 2.

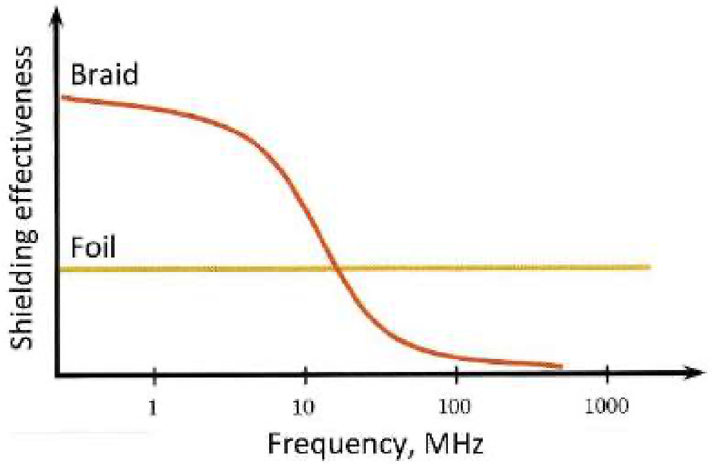



*Fig. 2:* Shielding effectiveness of two kinds of screens.

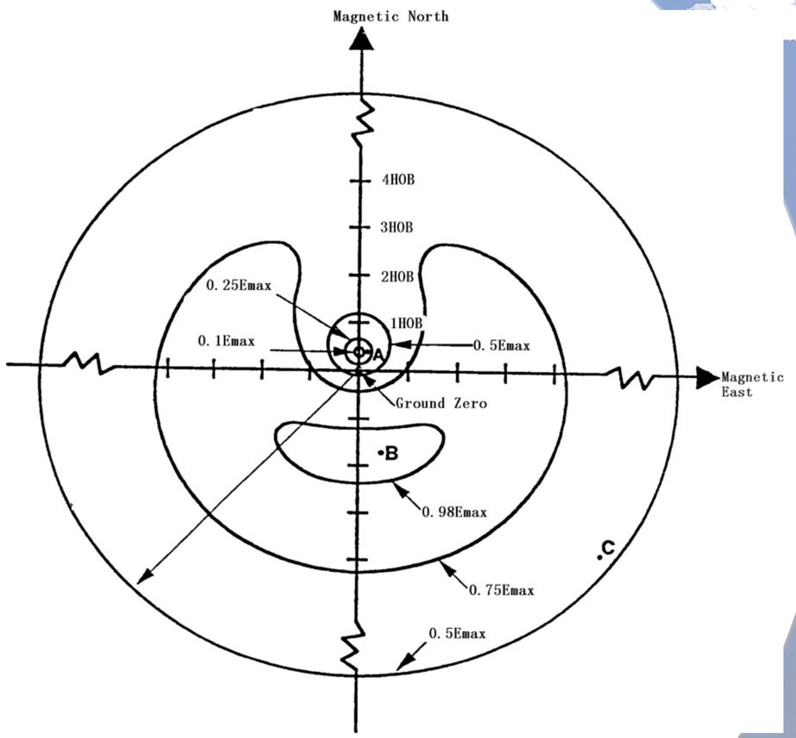



Fig. 3. Typical variations of peak electric fields on the Earth's surface for a high altitude nuclear burst.

TABLE I
THE ELECTRIC FIELD PEAK VALUE DISTRIBUTED ON THE GROUND FROM A 100 km HOB, 1 MT YIELD BURST

| Location on the Ground (Projection Point on the Ground from the Explosion Center) | Peak Electric Field $E_\psi$ (V/m) |
|---|---|
| 50 km to the north | 2866 |
| 26 km to the north | 11447 |
| Ground zero | 20777 |
| 57.7 km to the south | 35494 |
| 100 km to the south | 40042 |
| 173 km to the south | 40227 |
| 247 km to the south | 37071 |
| 290 km to the south | 34802 |
| 514 km to the south | 30796 |

# Cui Meng, Member, IEEE
# 1 Mt, 100 km

EPRI

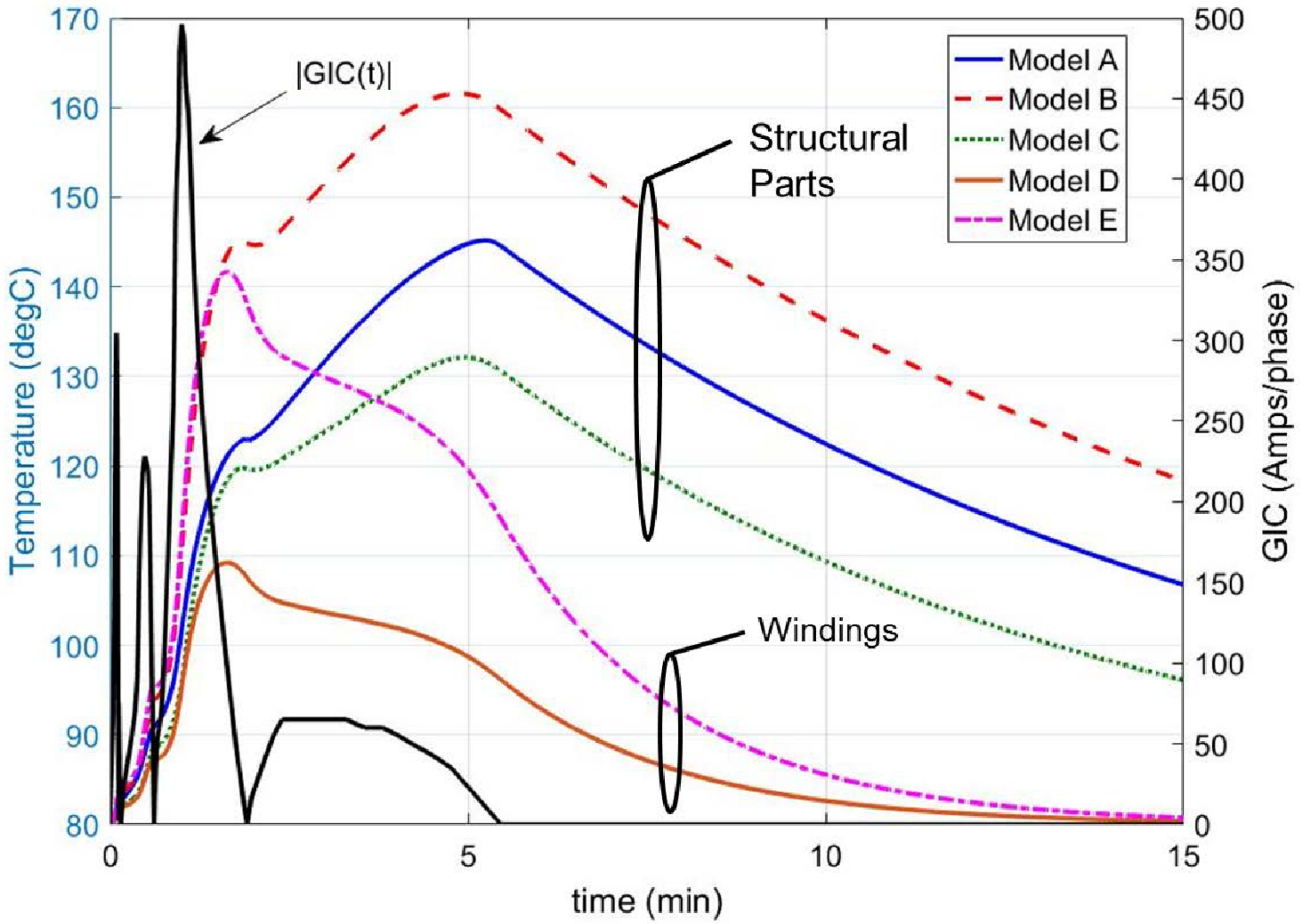



**Figure 3-2**
**Example time-series hotspot temperature calculation results using all five thermal models**

EPRI

**Table 1-2**
**Results of voltage stability analysis**

| Target Location | Interconnection | Generation Tripped (MW) | Load Tripped (MW) | Simulation Time (Sec) | Simulation Converged (Yes/No) | Voltage Collapse (Yes/No) |
|---|---|---|---|---|---|---|
| L01 | A | 12,001 | 5,440 | 112 | Yes | No* |
| L02 | A | 11,066 | 5,598 | 112 | Yes | No* |
| L03 | A | 27,543 | 13,654 | 112 | Yes | Localized Possible** |
| L04 | A | 11,767 | 22,083 | 61.05 | No | Yes |
| L05 | A | 50,729 | 60,303 | 60.87 | No | Yes |
| L06 | A | 25,864 | 13,000 | 112 | Yes | Localized Possible** |
| L07 | A | 15,320 | 8,309 | 112 | Yes | No* |
| L07 | B | 81,149 | 25,715 | 8.33 | No | Yes |
| L08 | B | 81,149 | 25,709 | 8.33 | No | Yes |
| L09 | C | 5,789 | 4,852 | 112 | Yes | No* |
| L10 | C | 8,162 | 5,317 | 112 | Yes | No* |
| L11 | C | 10,482 | 9,749 | 56.5 | No | Yes |

* Automatic generation control (AGC) and/or operation of under-frequency load shedding schemes would be necessary to maintain system frequency beyond the 112-second simulation period, and the inability to perform these functions could result in instability.
** Simulation results indicate bus voltages would eventually recover, but a large area (the size of a state or more) experienced significant voltage depression (0.5 per-unit or less) at the peak of the E3B. Localized voltage collapse is possible.

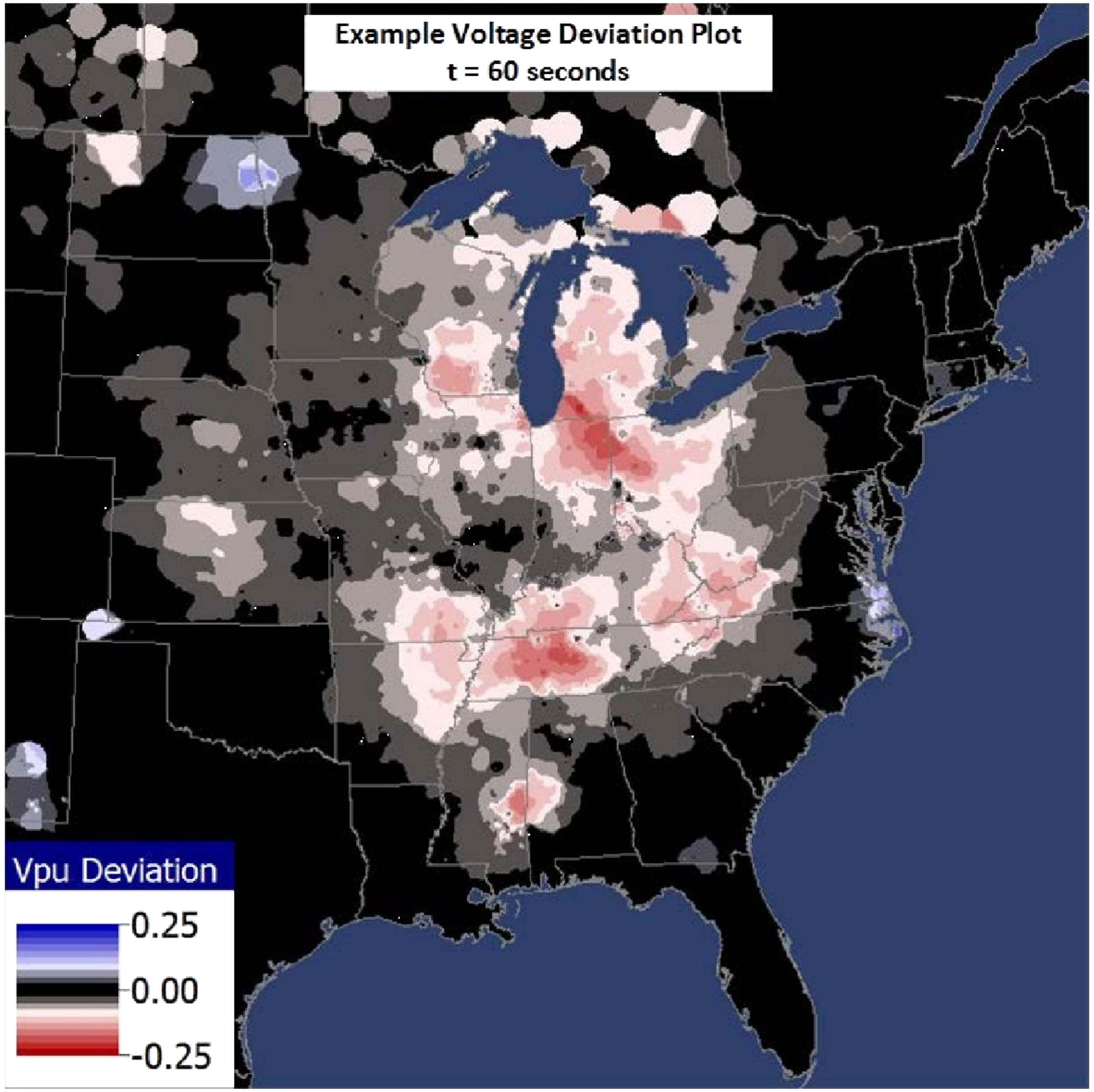



**Figure 1-13**
**Example area of bus voltage deviation in per-unit from the initial value at t = 60 seconds**

# Threat Potential

- Nominal elevation 200 km to 400 km (zero at 40 km)
- Blast size ranging from 125 k Ton to 1,000 k Ton
  - 1,200 k Ton device weighs 2,400 lbs
  - WW2 test blast was about 20 k Ton
  - “Suitcase” bomb might be 3 to 5 k Ton

# Damage Potential

- Generating Facilities
- Transmission Lines
- Distribution
- Sub-stations
- Data Centers and Control Facilities
- Communications Networks

# References (page 1)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