International Efforts on Electromagnetic Threat (E-Threat) Analysis and Mitigation

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Outline

- Background
  - EIS Council
  - E-Threats

- International E-Pro Report

Electric Infrastructure Security (EIS) Council

EIS Council: Created at the suggestion of senior government representatives from the U.S. and U.K.

- International coordination, research and education on electromagnetic threats (e-threats) to critical infrastructures

U.S.-based non-profit research and education NGO

- Offices: United States, United Kingdom* and Israel

* Hosted by HJS, EIS Council partner organization

EIS
SUMMIT
Welcome
EIS
SUMMIT
The Electric Infrastructure Security Summit
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Electromagnetic Threats (E-Threats)

- Geomagnetic Disturbances – GMD
- High-Altitude (Nuclear) EMP – HEMP
- Intentional Electromagnetic Interference – IEMI
- Impact Electric Grids (and other Critical Infrastructure Sectors)

International E-Pro Report

- E-Pro = Electric Grid Protection
- EIS Council is developing the E-Pro Handbook, designed to be a tool for grid owner-operators, based on best-practice information sharing.
- International E-Pro Report is a first step: gather and summarize (high-level) e-threat analysis and mitigation activities from 11 countries.

International E-Pro Report

Countries

- UK
- Norway
- Sweden
- Finland
- Germany
- South Korea
- Japan
- Australia
- New Zealand
- South Africa
- Israel

Majority of e-threat analysis and mitigation is focused on GMD, though some HEMP and IEMI work is underway.

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Country	Transmission Line Length (km)	Number of Substations	Operating Voltage(s) (kV)
USA/Canada	320,000	2100	138, 230, 345, 500, 765
United Kingdom	20,000	337	132, 275, 400
Norway	10,900	140	132, 220, 300, 420
Sweden	15,000	150	220, 400
Finland	14,000	100	110, 220, 400
Germany	34,776	430	220, 380
South Korea	31,249	749	154, 345, 765
Japan	NA	NA	187, 275, 500
Australia	43,775	NA	66, 132, 220, 275, 330, 500
New Zealand	12,000	174	110, 220
South Africa	28,995	153	132, 400, 765
Israel	NA	25	161, 400

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International Organizations

- International Electrotechnical Commission (IEC)
- European Space Agency (ESA)
- EURISGIC

Insurance Sector

- Lloyd's
- Allianz
- Zurich
- Swiss Re
- M.O.R.E. 27

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UK

The UK National Grid has taken important steps in EMP/GMD resilience. Key points of interest are:

- Transformer GIC withstand design – National Grid has determined that replacement transformers on the national grid should be of three-limb design, for robustness against GIC impacts. They have also completed a survey of all system transformers, identifying vulnerable transformers.
- GIC Monitoring – The U.K. has installed a GIC monitoring capability and the GIC monitors are tied into the real-time Smart Asset Monitoring System.
- "Extreme Event" updated from 1989 Quebec storm to 1921 Railroad storm.
- Transformer Spares – National Grid requires a spare transformer stockpile.
- IEMI protection – National Grid has determined that risk management strategies for IEMI are similar in nature to those for cyber security. As such, several sites have been assessed and mitigated for IEMI through component hardening and increased security measures.
- No explicit National Grid policy or practice exists for HEMP protection. However, the extensive efforts by the House of Commons Defence Select Committee on this subject indicate a growing national interest in efforts for EMP protections. Meanwhile, the fact that both GMD and IEMI are addressed will certainly have HEMP protection benefits.

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Norway

Norway's experience in dealing with GMD and EMP include the following:

- GIC and EMP/IEMI regulatory requirements – Norway's Contingency Regulations specify that Statnett SF must mitigate risks associated with GMD and EMP/IEMI. The requirements are "performance based", and do not prescribe any specific actions that must be taken, or technology that must be used.
- GIC Study and Monitoring – Norway commissioned an extensive study of GIC impacts on its systems in 2000, and has a robust GIC monitoring capability, supplying situational awareness that aids in executing emergency operational procedures.
- Emergency Operation Plan Testing – Norway requires that plans be in place for dealing with extraordinary situations, and requires the plans to be tested periodically.
- Future Grid Planning With GMD and EMP In Mind – Norway's planned expansion will be done using technology determined to be more resistant to GMD and EMP, thus building in resilience and increasing the reliability of the whole system.

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Sweden

Sweden's experience with GICs and Svenska Kraftnät's efforts to mitigate GIC effects include the following:

- Nearly a dozen G5 class GMDs have affected the Swedish grid in the last ~50 years.
- Svenska Kraftnät's policy is now to use three-legged, core-form transformers wherever possible in the grid.
- GIC withstand standard of 200 Amps DC for 10 minutes at full load.
- Svenska Kraftnät plans to expand its GIC monitoring capability.
- Svenska Kraftnät may consider the use of neutral ground protection for identified high-risk transformers.

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Finland

Finland's basic approach to GMD protection is simple and hardware based:

- The transformers used are of the design most resistant to GIC (3-limb, 3-leg core) and any new transformers will also be of the same type;
- Their long 400 kV transmission lines are series compensated, which blocks GIC flows in those lines; and
- Their transformers are grounded using coil reactors that dampen GIC flows in the transformer neutrals.

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Germany

Though Germany is in the nascent stages of studying and addressing the GMD/EMP risk for its electrical networks, there are a few points of interest that should be noted:

- Germany has begun a GIC monitoring campaign, with monitors being placed at several key grid points.
- The change in German energy policy away from nuclear and toward renewables will affect the resilience for GMD/EMP in two important ways:
  - More electricity will be transported over the transmission grid since the distance of electricity generation and consumption is increased, on average, potentially leading to higher GIC vulnerability.
  - Depending on how the phase-out of nuclear power plants is done, and on the long term plans for handling and cooling spent nuclear fuel rods, this change could reduce the concern of nuclear accidents caused by loss of outside power (LOOP) events.

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South Korea

- While studies have suggested there may be potential for significant GIC flows in South Korea's Power Grid, no mitigation steps have yet been taken against this hazard, according to information made available for this report.
- Given South Korea's assumptions for scenarios and field strength, a nuclear EMP attack would inflict widespread damage on South Korean society. While unclassified information is not available to indicate whether South Korea has taken steps to protect civil infrastructures, it is clear that Seoul has concerns over the safety and security of critical assets and military facilities.

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Japan

- 2000 Metatech study on the Chubu system measured GICs of 30-40 Amps for “low level” storm.
- While Japan has focused on changes to its power generation posture – in particular the nuclear power sector – the risk of GMD has not prompted further study or risk mitigation strategies.
- The Fukushima nuclear power plant disaster was precipitated largely by the loss of power from the electric transmission system, and coincident destruction of backup diesel power systems. A significant GMD or EMP event has the potential to cause a similar, and possibly more serious, loss of outside power (LOOP) event in Japan.

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Australia

- Although Australia has historically had almost no experience with GMD events, a recent study measured GICs in the transmission system. A GIC monitoring pilot study (8 sites) has begun in Australia, better situational awareness and understanding of GMD/GIC effects on the system.
- AEMO now has in place GMD-specific operational procedures to mitigate effects of GMD on their systems. Though AEMO acknowledges that operational procedures are somewhat limited compared to hardware-based solutions, they have deemed them acceptable, since GMD risk is considered to be much lower than for other systems (such as Quebec).

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New Zealand

New Zealand's experience in dealing with GMD includes:

- GMD power grid incident – In spite of multiple factors implying minimal risk, New Zealand's power grid experienced a transformer fault and trips due to a GMD event during a modest solar storm. As a result, New Zealand's power authority has been proactive in developing protective strategies for GMD.
- Operating procedures for GMD – New Zealand's fundamental approach is to take lines out of service that connect to vulnerable transformers. This is opposite to the NERC-recommended operational procedure, which calls for putting lines back into service as a preventive posture for GMD.
- GIC Monitoring – New Zealand has a robust GIC monitoring capability, and the GIC monitors are tied into the operation control centers, supplying situational awareness to aid in executing the operational procedures.
- Hardware approaches for GMD – New Zealand has outfitted several of its key transformers with neutral grounding resistors and capacitors, which have been in place beginning in 1990. This technology has now been fielded for over two decades, and has been shown to be effective in protecting transformers from stray DC current while not adversely affecting system performance.

New Zealand cont'd

"Earthing" resistors on 32 transformers and capacitive elements on 2 transformers

Transformer	NER Resistance (Ohms)	Rated Winding Volts (kV p-p)
ASB T1	1.5	220
ASB T3	1.5	220
ASB T8	3.2	220
ASB T10	3.2	220
AVI T1	10	220
AVI T2	10	220
AVI T3	10	220
AVI T4	10	220
BEN T27	60	220
BEN T28	21.5*	220
BEN T29	60	220
BEN T30	Capacitive 4.2mF*	220
BEN T42	5.5	220
BEN T44	5.5	220
BEN T46	5.5	220
BRY T5	1.5	220
BRY T6	1.5	220
BRY T7	1.5	220
ISL T1	2	220
ISL T2	2	220
ISL T3	2	220
ISL T6	2	220
ISL T7	2	220
ISL T9	4	220
TIM T5	4	220
TIM T8	4	220
WTK T21	5	220
WTK T22	5	220
WTK T23	3	220
WTK T24	3	220
HAY T25	Capacitive 4.2mF*	220
KWA T1	20	110
KWA T2	20	110
WIL T8	6.5*	220

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South Africa

- The experience of the South African Halloween storm, with the ESKOM assessment of extensive, GIC-induced transformer damage, is an important reminder that GMD can affect mid- to low-latitude countries. Long-duration, low GIC flows (several amps) can be enough to weaken transformers, though there may be no immediately apparent damage or system instability.
- South Africa is in the early stages of increasing its resilience to GMD, through the use of better GIC monitoring and consideration of operational procedures to mitigate GIC flows.

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Israel

Israel has completed a comprehensive vulnerability analysis of the entire nation-wide IEC system. While details are restricted, additional analysis, plans and protective measures are in progress to mitigate those vulnerabilities, to achieve a strong level of EMP/GMD resilience for Israel's electric infrastructure.

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IEC

- The International Electrotechnical Commission, based in Geneva, Switzerland, has developed an open-source, unclassified set of descriptive material and standards for use in addressing EMP threats.
- IEC Commission material available includes electromagnetic compatibility assessment, EMP threat measurement, simulation and related standards and guidance, and associated information related to protection approaches. Detailed information can be found on the Commission's website.

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IEC

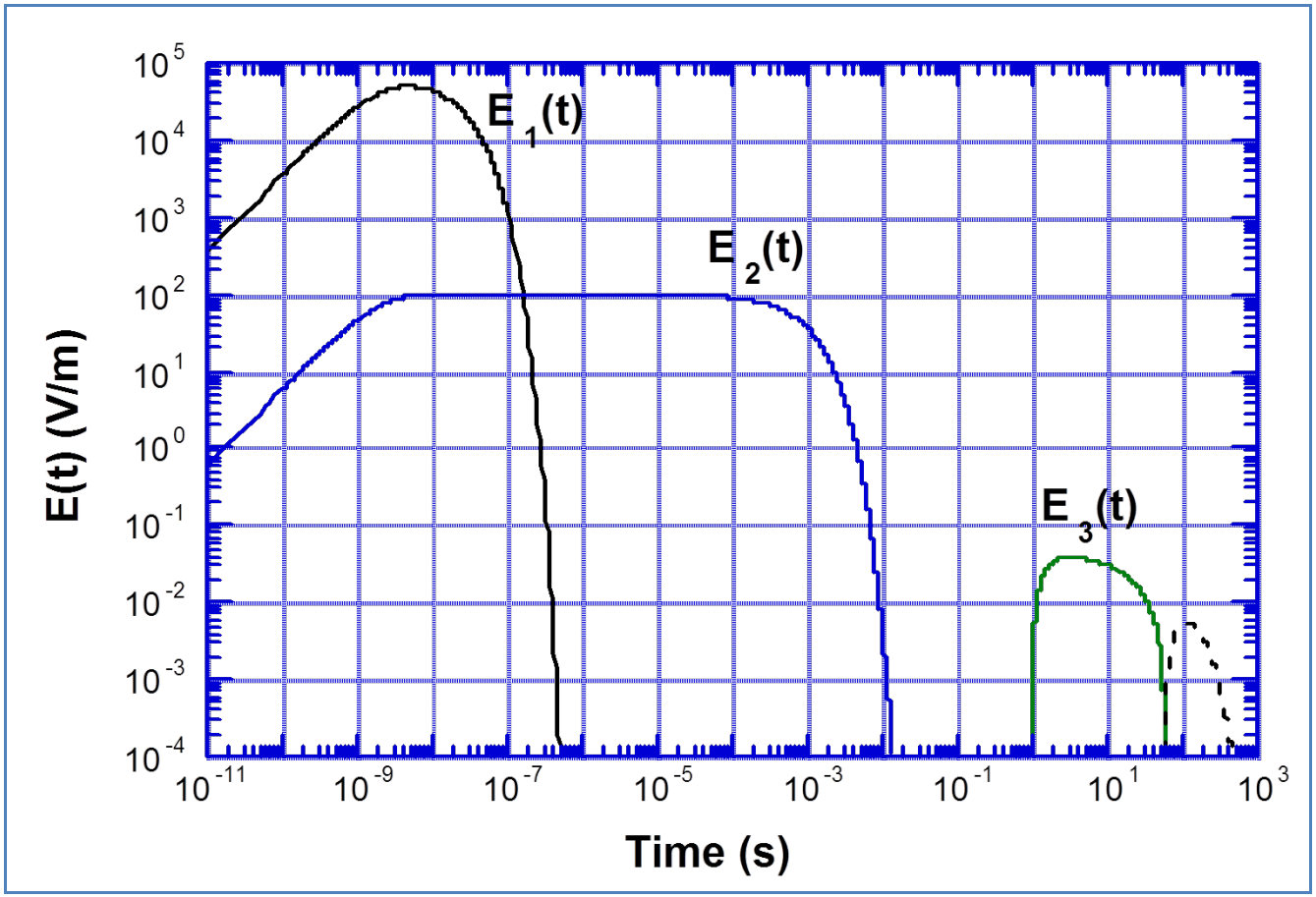

Figure 5.1.1. Three portions of the EMP electric field waveform (E1, E2, E3) in volts/meter from IEC 61000-2-9

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Insurance Sector

- As the world's largest business sector, and the industry with the closest association with risk projection and analysis, the insurance sector has become increasingly involved in assessing societal risks associated with severe space weather.
- Many of the world's largest insurance markets and corporations have become involved in assessing the risks, reviewing historical space-weather associated equipment failure data, and projecting their assessment of the implications for risks to societal and business health and continuity.