*CIGRE GOTF 2022*

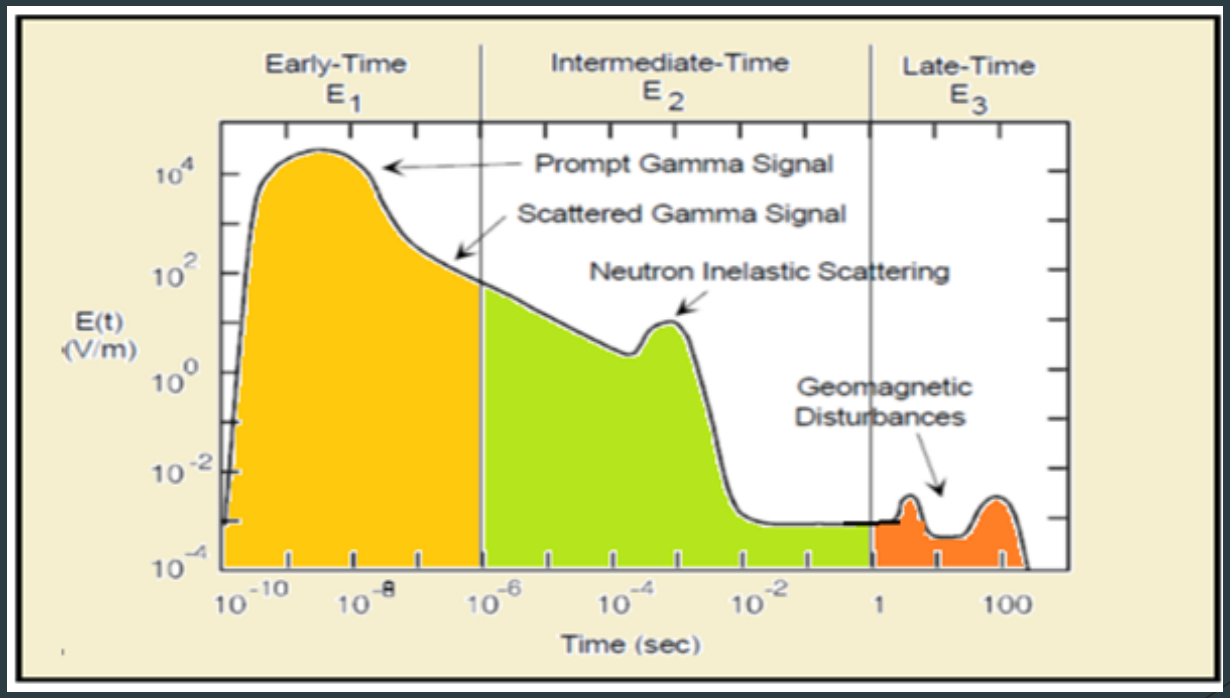
# Equipment Protection From Geomagnetically Induced Currents (GIC)

Alberto Ramirez Orquin

Vanessa Ramirez

Resilient Grids, LLC

# IEC Extracts: EMP Waveforms



# IEC Extracts

- A nuclear EMP (NEMP) field test has never been carried out in the Free World
- IEC member, the only country which has systematically performed full-scale NEMP tests since 1962
- Data depicted was established back in the XX century (not significantly updated since)
- IEC member has repeatedly claimed achieving substantial higher magnitudes

# Phenomena Sequence Parallels

| EMP | E1 | E2 | E3 |
| --- | --- | --- | --- |
| Solar Storms | Solar Flare | Radiation Storm | CME |

# *GMD Operating Procedures and Reliability Standards*

NERC-GMD Task Force

Impact Assessment of an incoming CME

# *GMD Operating Procedures and Reliability Standards*

Based on early GMD alerts, enabling the impact assessment of an incoming GIC via state-estimation algorithms

Scheme focuses on grid voltage profile/stability, power transfer, transformer thermal response, etc

Network reactive power reconfiguration/rationing, including plant curtailment or derating to keep the power system in synchronism

# *Further Challenges for EMP-E3 GIC*

GIC comparing favorably with apparatus load currents

GIC establish DC offsets to AC load currents for sizeable copper losses

Significant copper losses, inherent transformer resilience not assured

# *EMP E3 Mitigation Prospect from the Operational Standpoint*

Very limited time for EMP alerts

EMP E3 pulse is preceded by ultrafast E1 and E2 waves

# *EMP E3 Mitigation Prospect from the Operational Standpoint*

- May not have the benefit of AC Breaker Operation
- Operational alternative may get seriously impaired

# *The Critical Importance of GIC Suppression*

GIC-magnitude, potential damage to major power equipment with a limited world supply; no USA Manufacturer

A Replacement/Recovery strategy to face formidable logistic challenges

# *Grid Security*

GIC-magnitude limitation a matter of endeavor in GMD/EMP network reliability engineering

Several attempts to suppress GIC have been studied for decades

# *US Government EO and Law for Grid GIC Control*

Coordinating Efforts to Prepare for the Nation for Space Weather Effect. (Presidential Executive Order, October, 2016)

Critical Infrastructure Protection Act [CIPA]. (US Law, December, 2016)

Coordinating National Resilience to Electromagnetic Pulses. (Presidential Executive Order, March, 2019)

# *Related US Government EO and Law for Grid GIC Control*

Institutional initiatives have prompted industry to a pressing installation of those mitigation devices for purposes of testing,  demonstration, proof of concept, as well as providing some protection, albeit unknown quantitatively

In practice, such a scheme has conveyed a sort of tentative process, discretely spotting units in different places of the power grid

# *Selected References for Grid GIC Control*


- Zhenhua Wang, Aster Amahatsion, Jovil Rajesh Benny Stephen, Larry Anderson, American Electric Power, **"GIC Flow Characteristics and Mitigation".** CIGRE USNC GOTF 2017 Symposioum Paper Session 090217.
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- Hong-zhan Nie et al.**"Optimal Governance of GIC in Power Grid Based on the Sensitivity Analysis Method"** March 2012DOI: Power and Energy Engineering Conference (APPEEC), 2012 Asia-Pacific
- A. Rezaei-Zare and A. H. Etemadi, **"Optimal placement of GIC blocking devices considering equipment thermal limits and power system operation constraints"**, *IEEE Trans. Power Del.*, vol. 33, no. 1, pp. 200-208, Feb. 2018.
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## *Conclusion from recent AEP Papers*

"The **effectiveness** of a neutral-blocking device is **very limited** if the deployment is in a small scale"

# *Significance of AEP Findings*

AEP conclusion is particularly significant

AEP Transmission, the largest EHV/UHV system in the nation (40,000 mi, 11 States )

# *Need for a Cost-Effective GIC Mitigation*

World experts had also concluded that only a massive grid device deployment would be required to suppress GIC and its harmful effects

A partial or incomplete implementation would render that mitigation effort ineffective setting winners and losers in a sort of grid GIC Rollercoaster

# *Need for a Cost-Effective GIC Mitigation*

By 2018 not known commercial installation of a GIC Blocking Device

Lack of utility industry record of units becomes a major deterrent for any significant deployment

# *Electric Utility Systems and Practices*

Equipment intended for a networkwide deployment must have well-known failure modes/rates to enable a full evaluation of their potential deteriorating impact upon the transformer forced outage rate (FOR)

# *Current Program of Blocking Devices*

- In-service, full-scale field testing as a fast-track vetting; not a proxy for a genuine utility record
- Phenomena with remarkable low frequency of occurrence and knowledge gaps
- Decades to hopefully achieve consistent results to enable such a massive commissioning

# *To Probe Further*

Need to keep striving for innovative concepts

Goal of a cost-effective mitigation device meeting all constrains without introducing unknown hazards of its own to the power grid

Concept conceived in simplicity, preferably with passive/static components with well-established failure modes/rates

# *To Probe Further*

Assembly primarily free from EMP-vulnerable sensing and switching functionalities (ideally in permanent connection)

Any technology meeting these attributes has then a prospect to achieve the required full grid installation in a secure and timely fashion

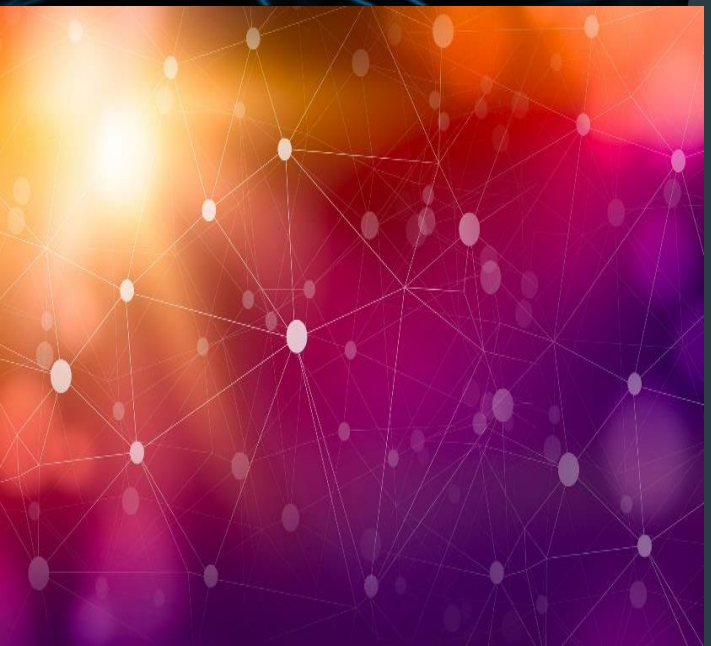
# *Conclusions*

Factors affecting this process were presented

Cautionary statement to industry concerning the problematic shortcomings of current strategy

Additional caveat considering the unfeasibility of validating experimental technology in a near future

Power grid stands the chance to remain unsecured for years to come



# *Thank you*

## *Resilient Grids LLC*

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