An EMP Mitigation Perspective: Systems and Components

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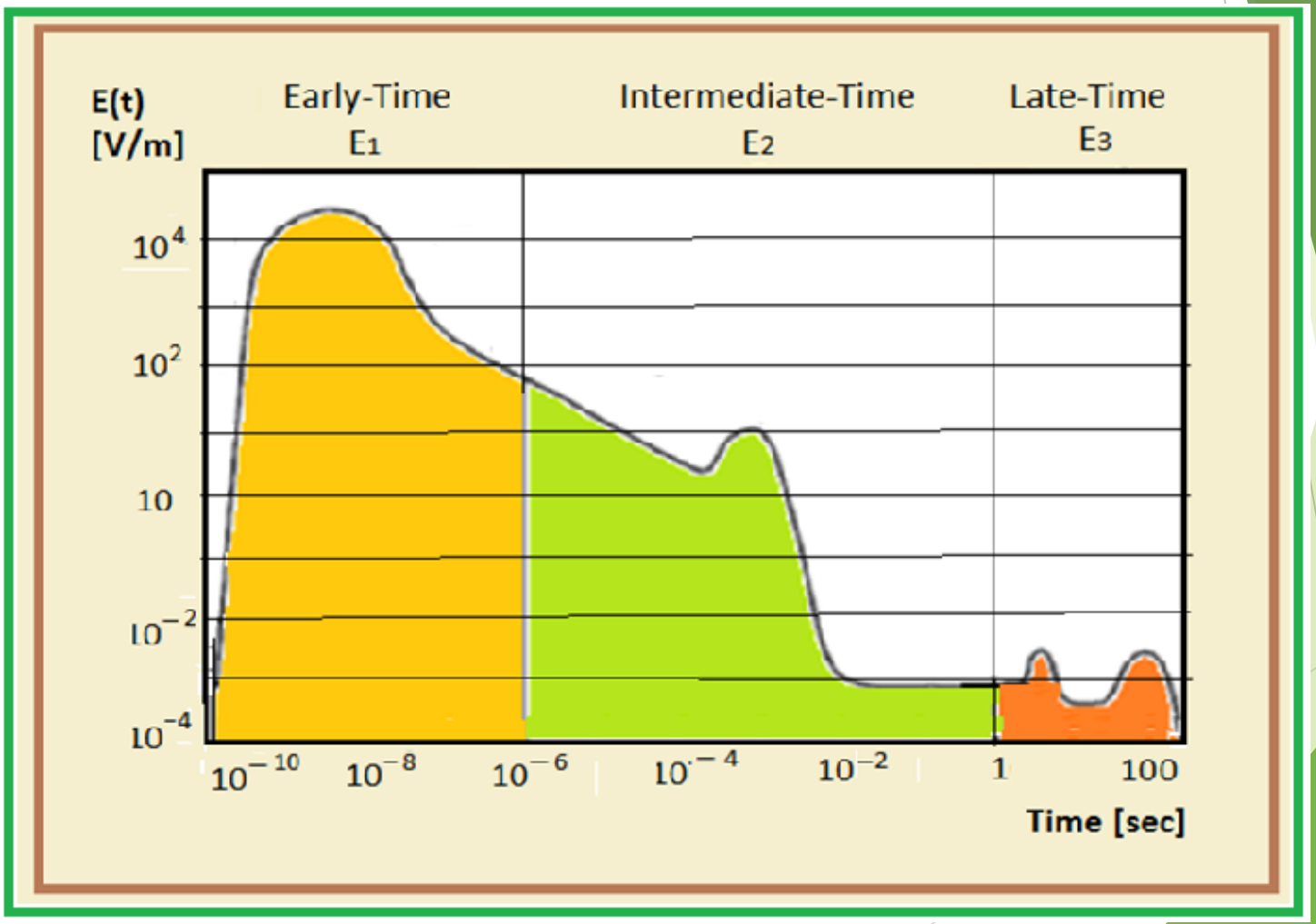
Nature of Electronic Magnetic Pulse (EMP)



Nature of EMP

EMP/E1 and E2 shock waves, ultra-fast overvoltage surges

Cannot couple with EHV Transmission lines

E3 pulse can couple with EHV Transmission lines

Similar phenomenon to Solar Storms

Nuclear EMP History

Soviet HEMP tests in the early 1960's were reported to have damaged power equipment

Russian military writings claim to have a super EMP weapon that can generate 200 kV/m*

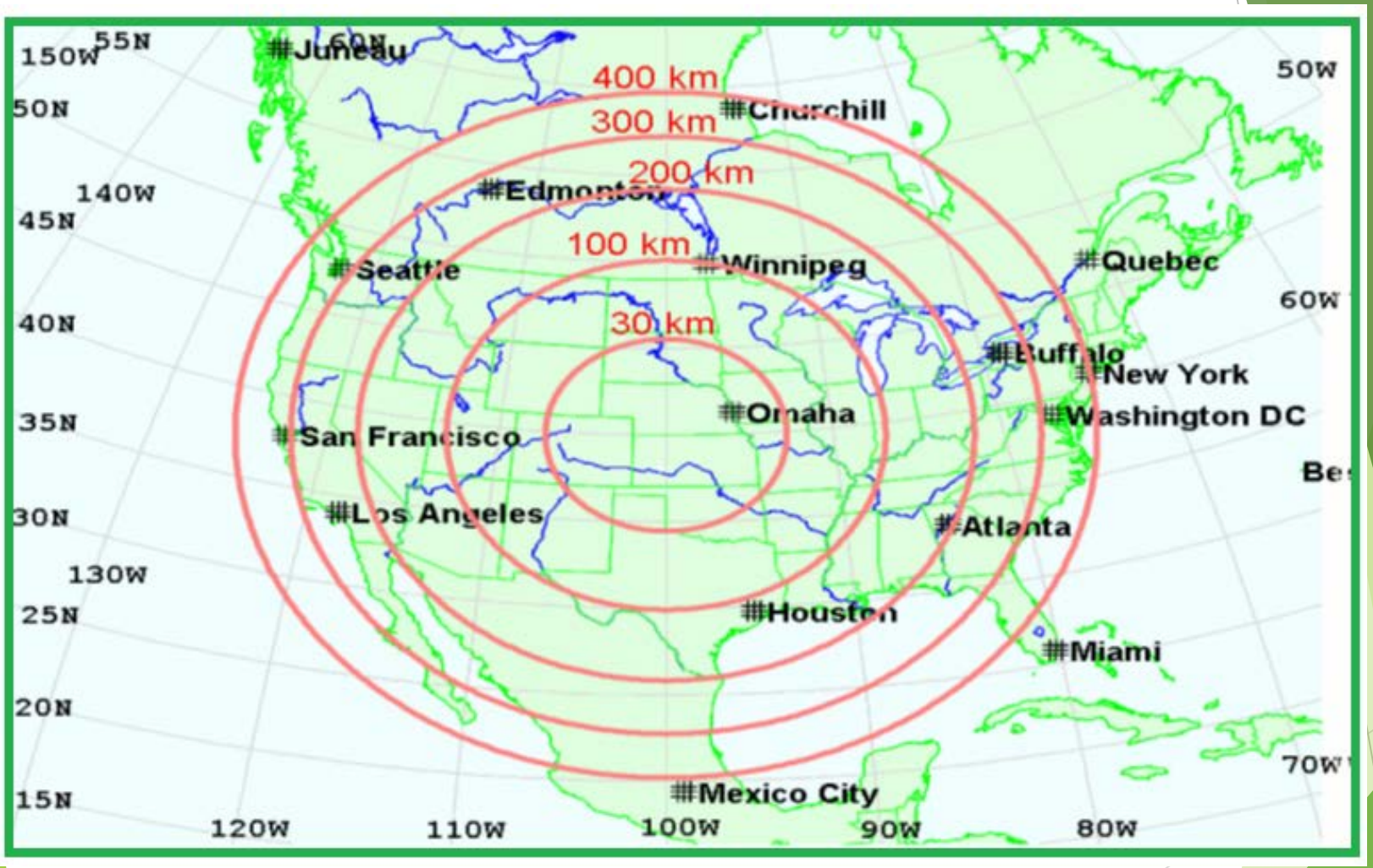
*Congressional Research Service, Clay Wilson, High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments," 2008

Current Nuclear EMP

Various countries have optimized nuclear weapons for HEMP impact

According to a recent published Pentagon assessment, NK is now capable of launching an EMP attack over the continental USA

HEMP Burst Height Sensitivity



HEMP exposed regions for several heights. Red circles show the exposed regions for the given burst heights, for a nuclear burst over the central U.S. [Oak Ridge National Lab]

EMP History

No specific EMP full-scale testing has ever been carried out in the Free World

Possible broad utility system blackouts

Long-lasting grid devastation prediction from E1 debatable

EMP Mitigation Strategies

Prevention

vs.

Recovery

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EMP Mitigation Attributes

Fundamentals

vs.

Electronic Sophistication

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EMP Mitigation Attributes

Fundamentals

Power System Basic Components
Generators, Transformers, Breakers, T&D
Auxiliary Services, Pumps, Fans, DC, Fuels,
Prime Movers, etc.

Electronic Sophistication

Computer and Information Systems,
Automation, Artificial Intelligence, Robotics
SCADA, EMS, DMS, PLC

The Early-Pulse Mitigation

Thousands of installations

Millions of components of very diverse nature, technology and vintage

A full preventative attempt to harden each item would consequently result in an overwhelming task

The E1 Early-Pulse Impact

Not direct impact to major power equipment

Insulation breakdown in electric/electronic circuitry

Large number of computer, microprocessors

Control centers SCADA/EMS/DMS/PLC

Distribution Lines and Transformers

The Early-Pulse Mitigation

Inherent built-in hardening takes place as compliant, new or refurbished, hardware constantly merges into the existing utility

Full duplication of key Control Centers

E1 or E2 shocks do not couple with EHV transmission lines and hence cannot damage major power equipment

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The Institutional Stance

DOE Electromagnetic Pulse Resilience Action Plan

The Joint Strategy identified five strategic goals:

1. Improve and Share Understanding of EMP: Threat, Effects, and Impacts
2. Identify Priority Infrastructure
3. Test and Promote Mitigation and Protection Approaches
4. Enhance Response and Recovery Capabilities to an EMP Attack
5. Share Best Practices Across Government and Industry, Nationally and Internationally

The Institutional Recognition

‘EMP and Geomagnetic Storm events have the potential to physically damage electrical and electronic equipment throughout North America’s critical infrastructure, notably including Extra-High Voltage transformers and industrial control systems like Supervisory Control and Data Acquisition (SCADA) systems’*

*NERC Executive Brief ‘Electromagnetic Pulse & Geomagnetic Storm Events’

Findings from a 2016 Research

Research funded by PSERC, DOE, NSF, EPRI, BPA, the State of Illinois DCEO, and ARPA-E*, concludes that: “The two key concerns from a big storm or an HEMP are:

1) Large scale blackout due to voltage collapse, and
2) Permanent transformer damage due to overheating”.

*ARPA-E, stands for Advanced Research Projects Agency-Energy

Need for GIC Mitigation

GIC currents, quasi-DC nature (up to 2 KA)

Saturate/overload the magnetic circuits of major power transformer and shunt reactors

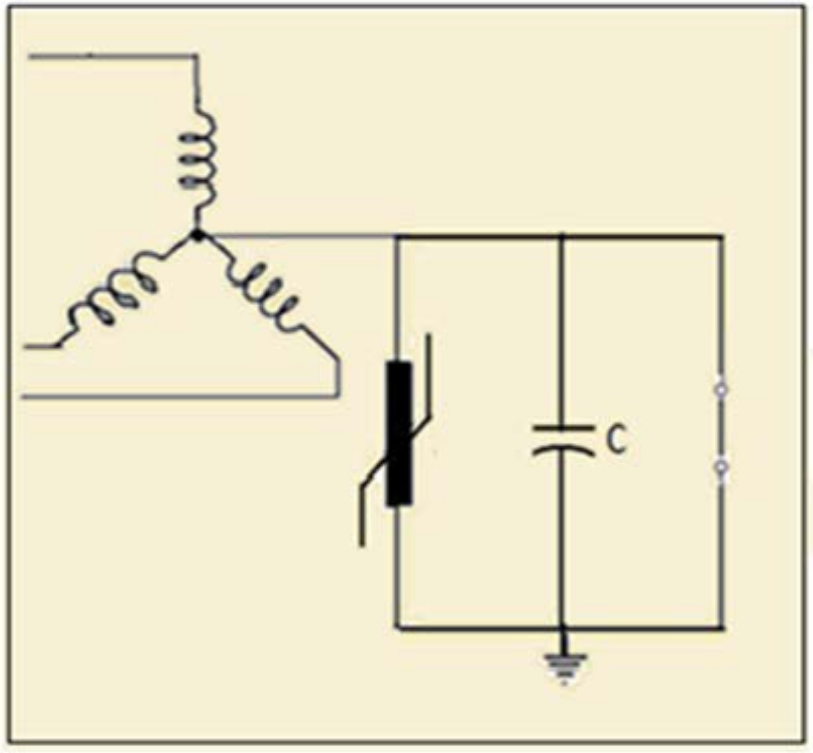
Ample spectrum of harmonics

Mechanical/thermal problems, including vibration and hot spots

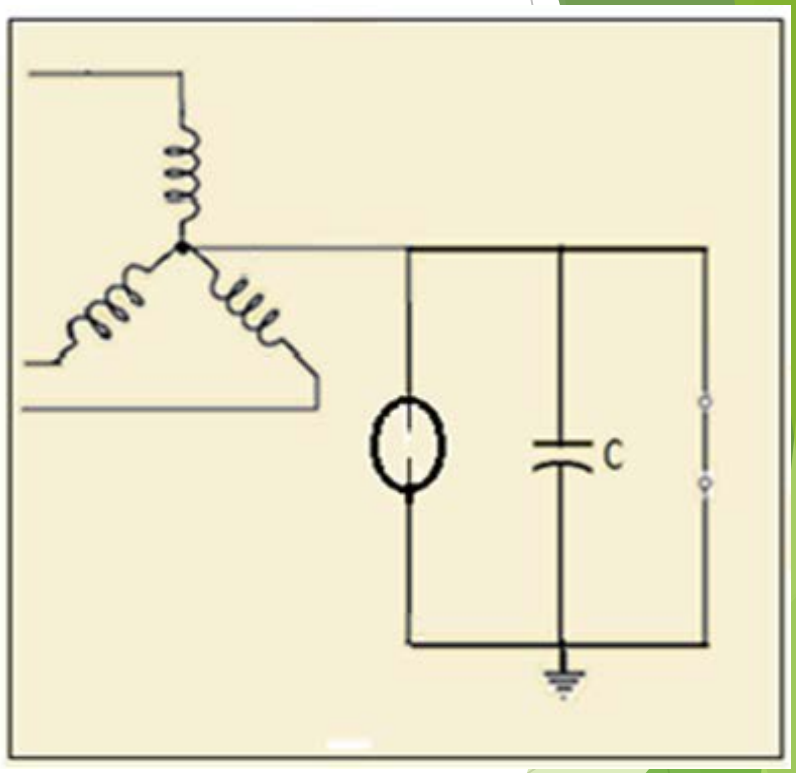
Transformer health index and expected loss of useful life

Permanent outage cannot be ruled out

Capacitor GIC-Blocking Schemes



Capacitor Neutral-Blocking Device



Alternative Capacitor Device

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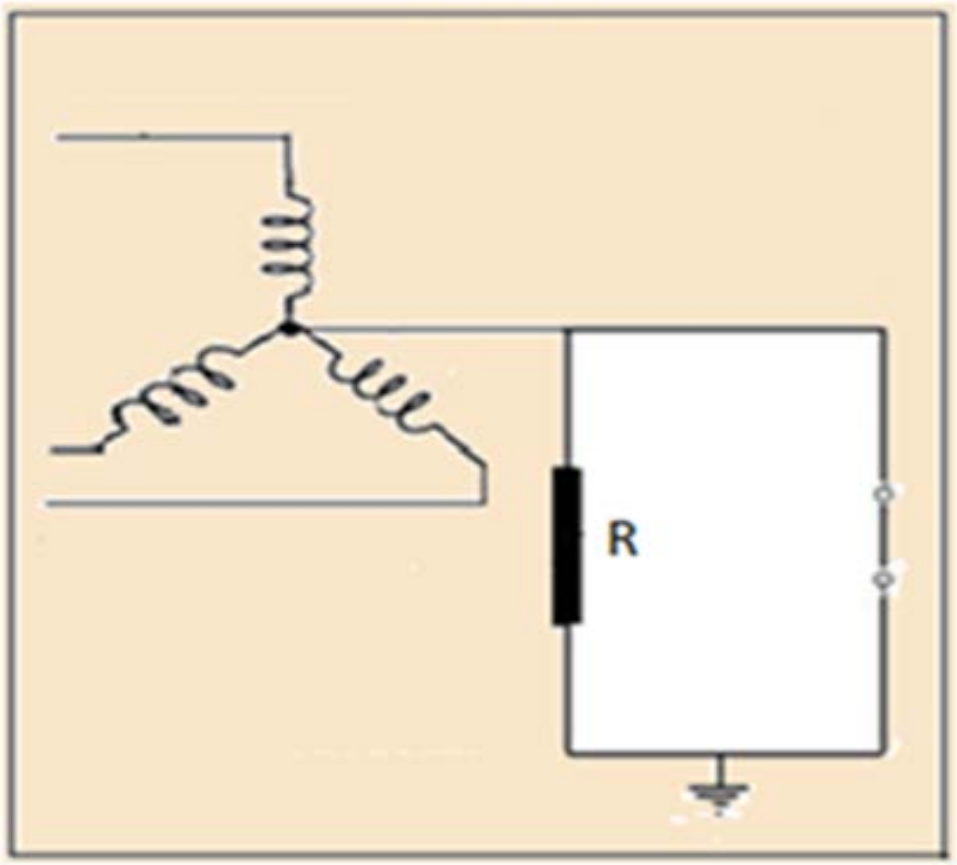
Resistor GIC-Reducing Concept



Resistor Mitigation Device

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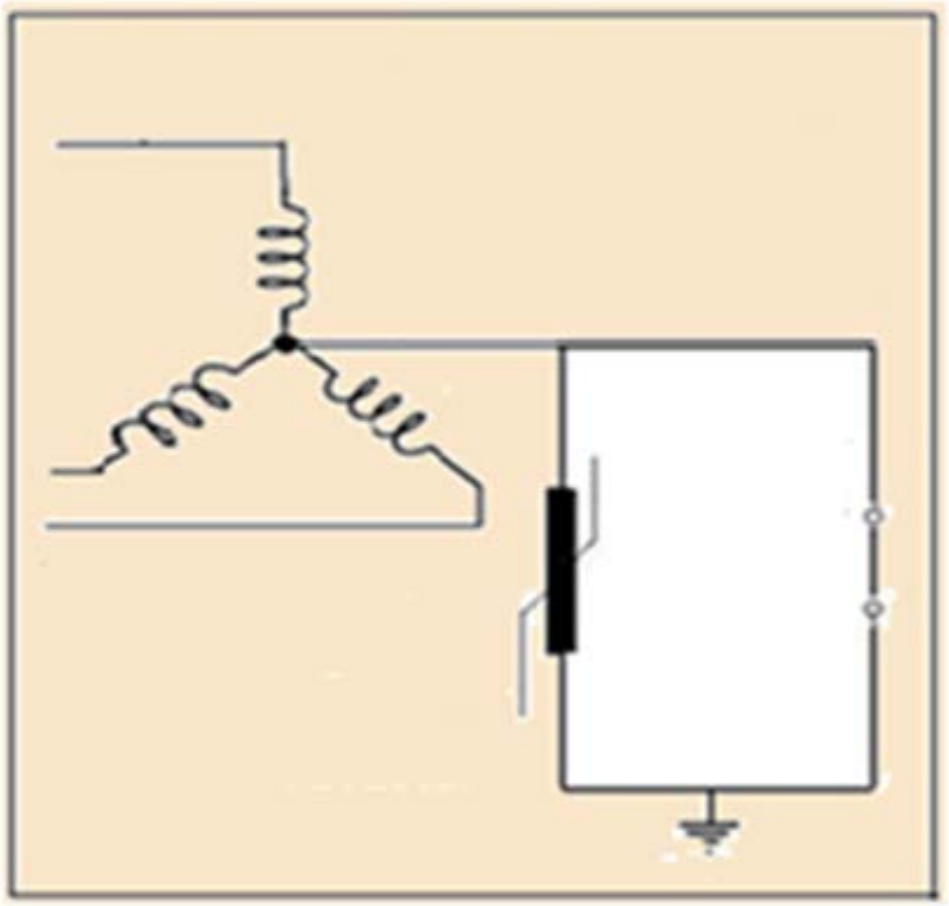
Surge Arrester GIC-Blocking Concept



Surge-Arrester Device

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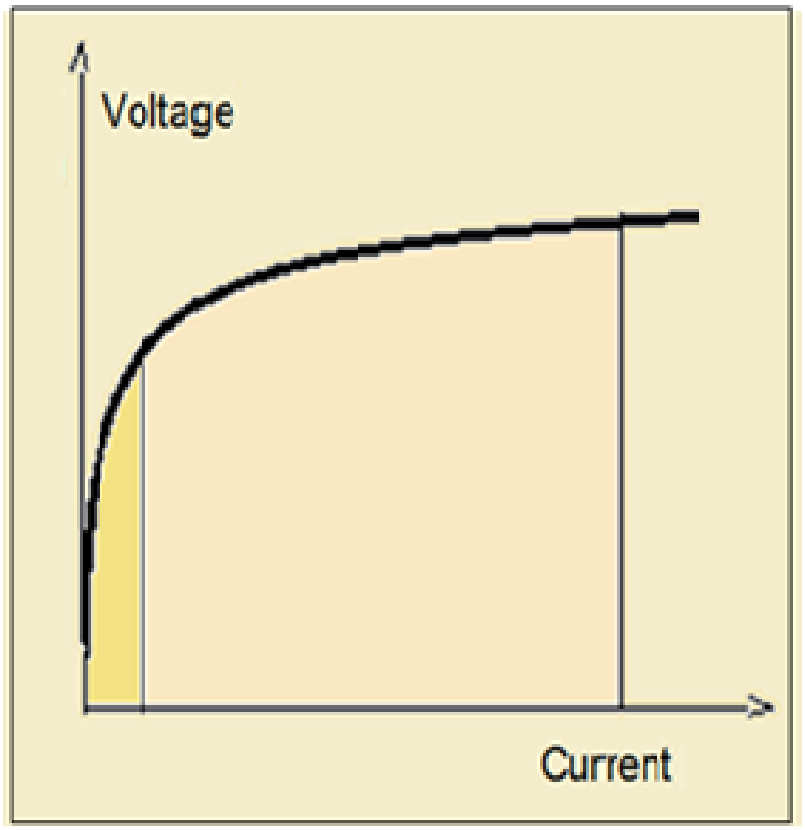
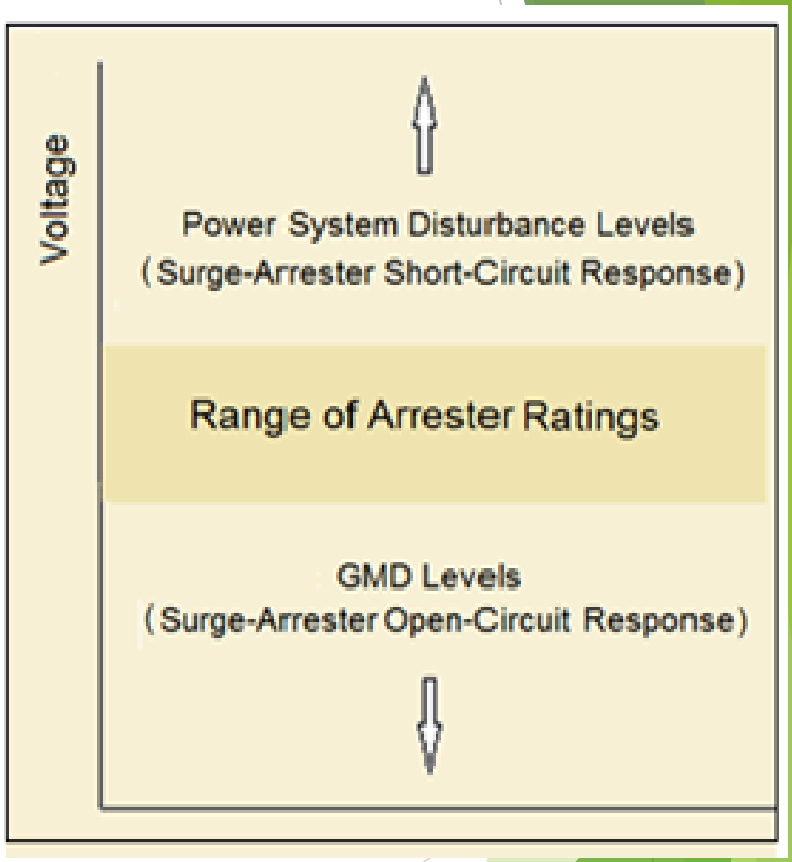
Arrester GIC-Blocking Concept



Typical Volt-Ampere characteristic of metal-oxide surge arresters



Comparative of transformer neutral voltage ranges

Probing Further, Technical Issues: Sensing and Deployment

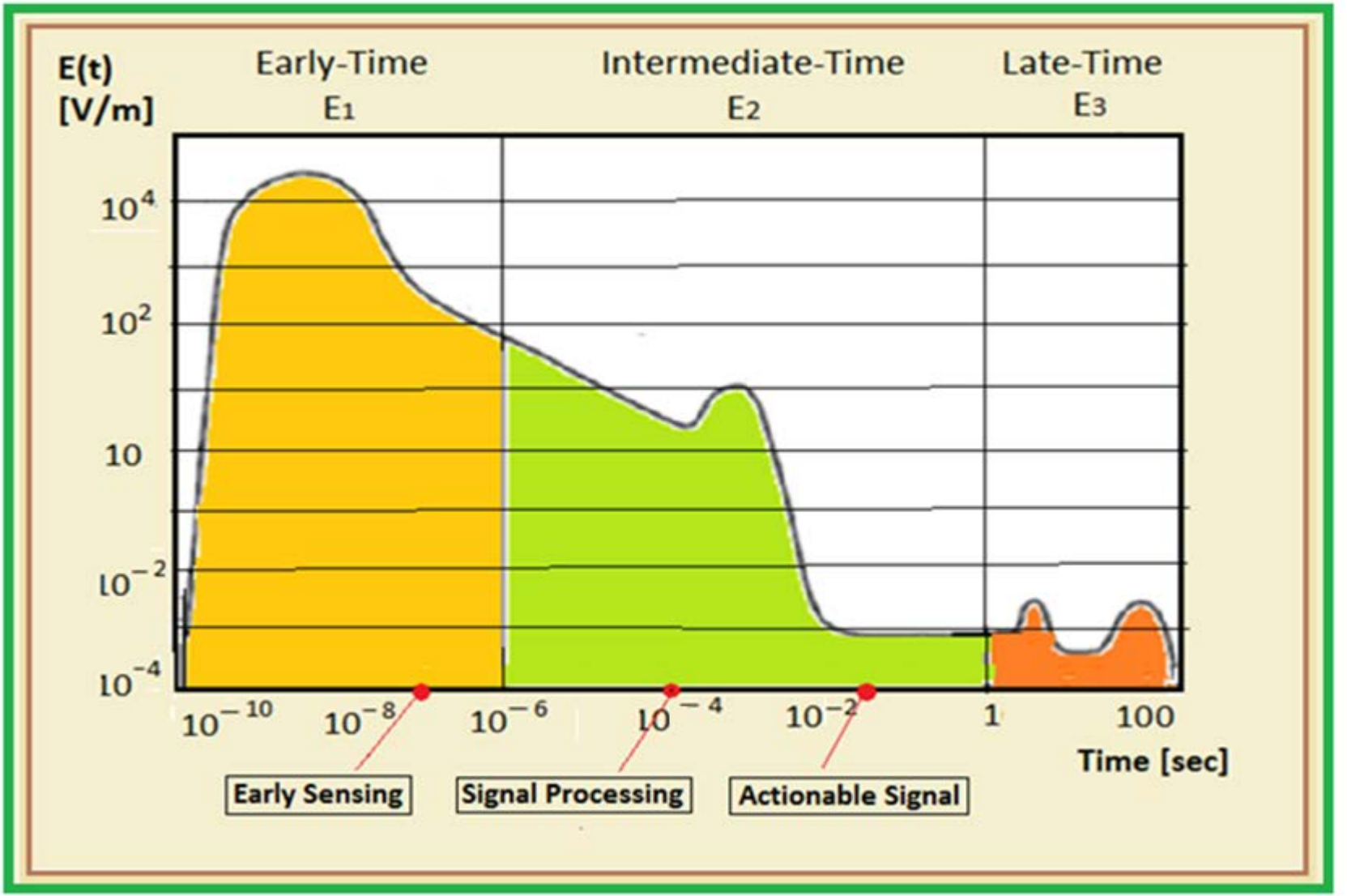
GIC detection and switching of mitigation devices

Severe EMP, a DC current-interruption challenge

E1 pulse not a menace to major power apparatus

E1 pulse not a challenge from sensing standpoint

Proposed Sensor with Actionable Signal



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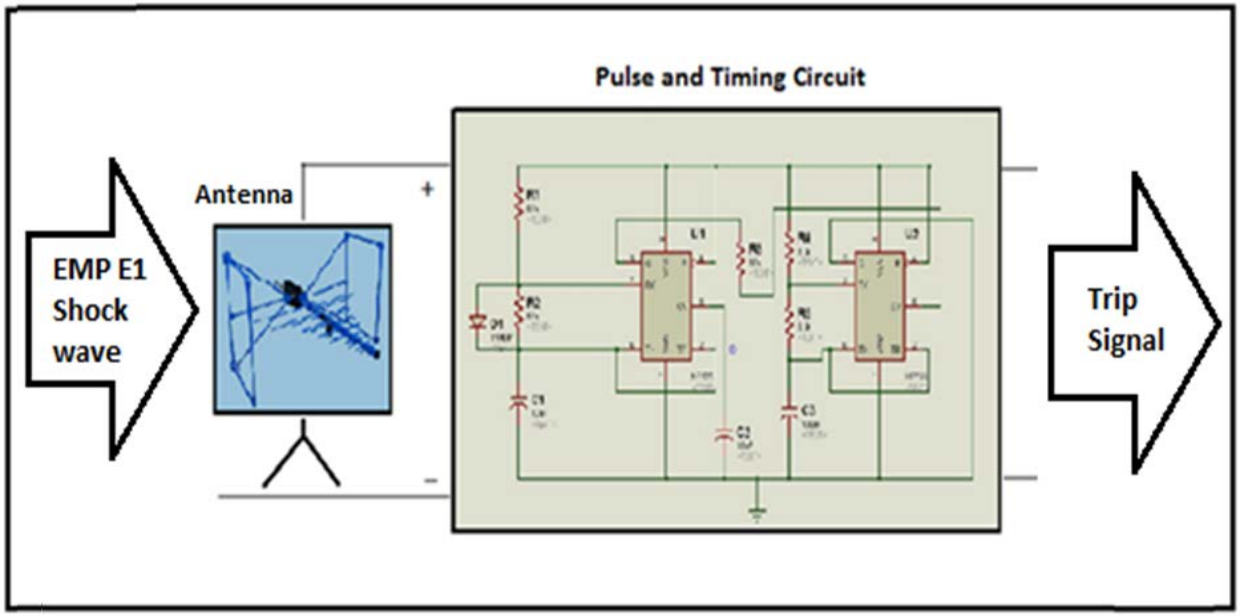
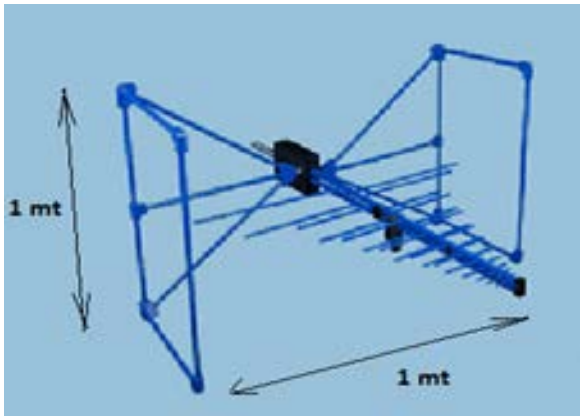
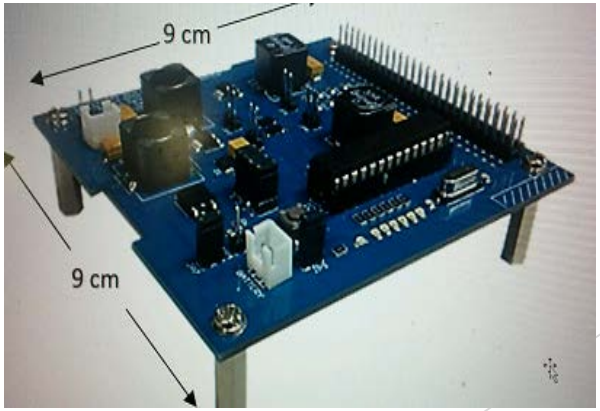
Proposed Sensor with Actionable Signal







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Questions?

Thank You

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