GMD/EMP E3 Non-linear Resistor Device Protection

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Vanessa Ramirez

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Cost-effective hardening of critical apparatus before solar or malicious GMD

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Device Development

Conceived minding the Electric Utility Industry conservative standpoint

Device conforms, follows well-established Electric Utility Systems and Practices

Concept avoids completely exotic gadgetry or applications having limited or no Electric Utility operating experience

Device - Industry’s long track record

Apparatus Neutral Grounding Non-linear Resistor applications

MOV Technology

Transformer Surge Arrester applications

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Design Objectives/Characteristics

- Effective GIC Blocking
- Simplicity
- Few Distribution-Class Components
- Minimal Footprint
- Minimal Grounding Impact
- Maintenance Free
- Minimal Cost

Design/Operation Objectives

- Minimal substation redesign
- Minimal command/control hardware
- Minimal command/control engineering
- No ostensible pitfalls

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Revisiting Non-linear Resistor Essentials in the Power System

Non-linear resistor, as a metal-oxide varistor (MOV) or as a surge arrester, has been a well-established technology of the industry for over half a century

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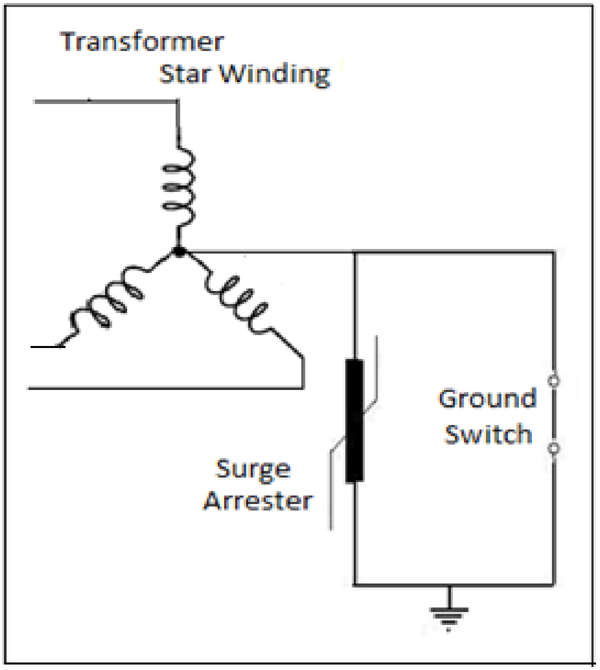
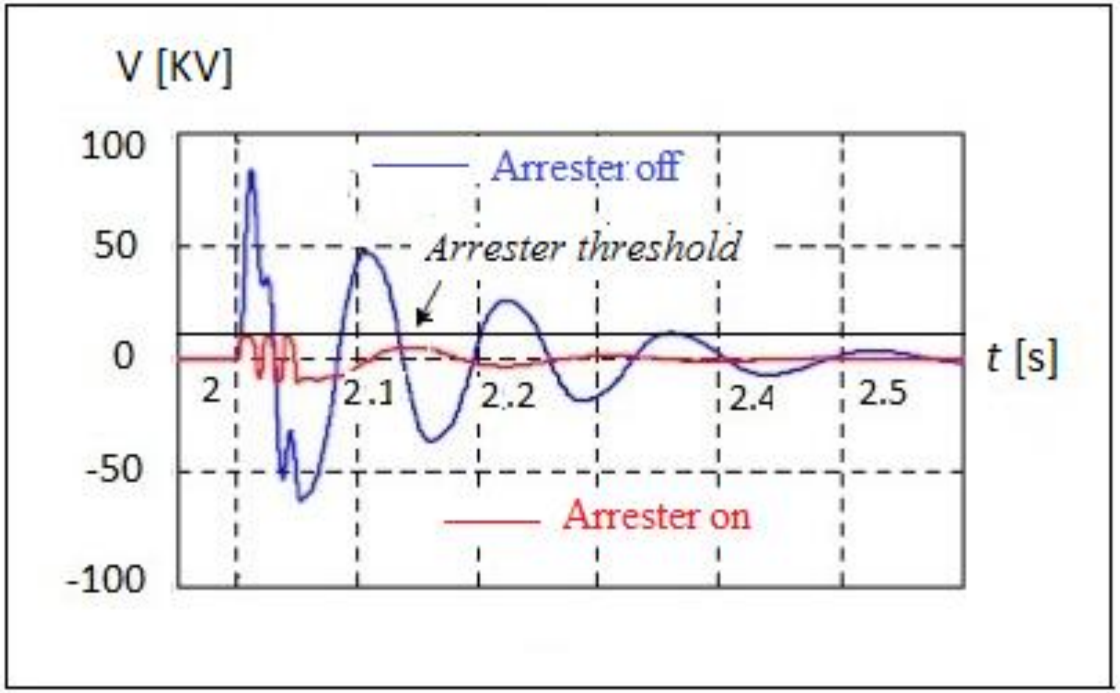
Revisiting Non-linear Resistor Essentials in the Power System



Revisiting Non-linear Resistor Essentials in the Power System

The Protective Functionality



SLGF Surge Arrester neutral voltage protection

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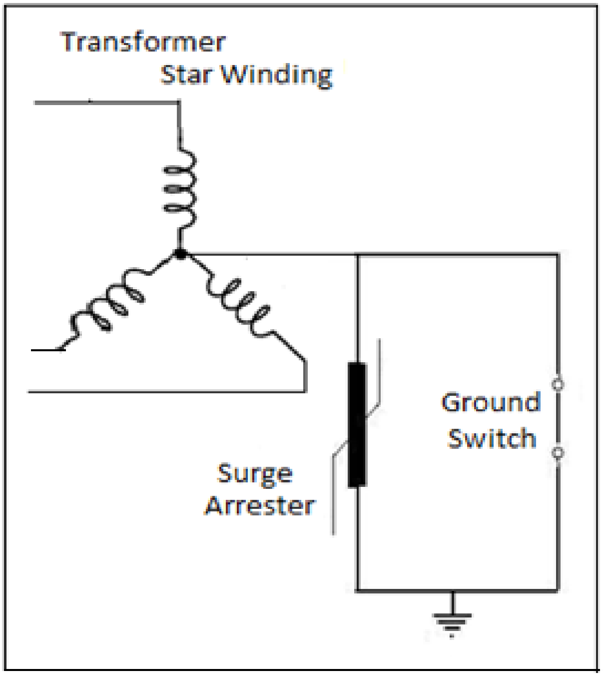
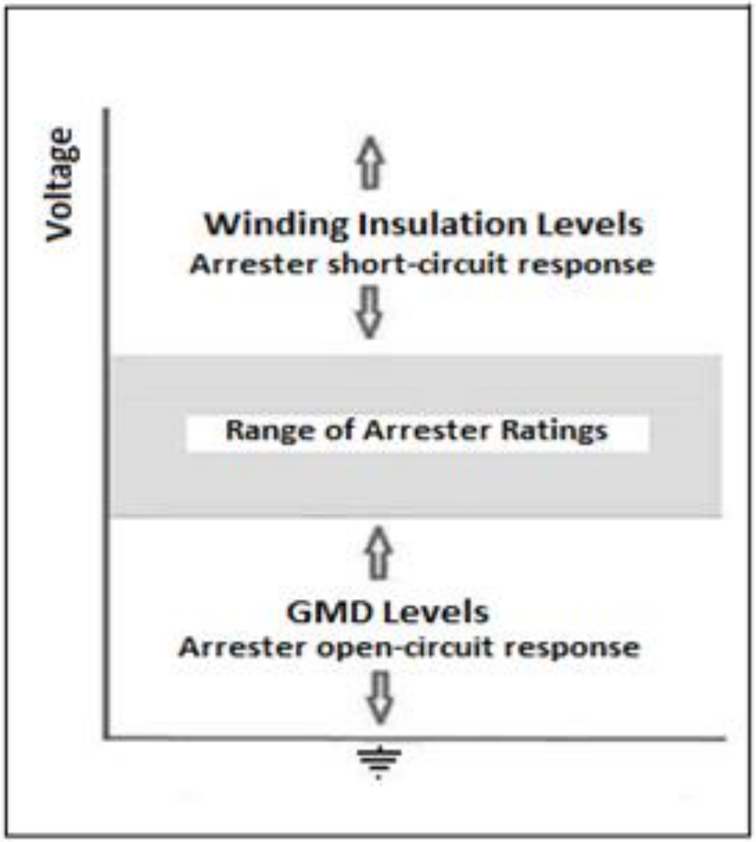
Revisiting Non-linear Resistor Essentials in the Power System

The GIC-Blocking Functionality Principle



Basic Non-linear Resistor
GMD Mitigation Device

Revisiting Non-linear Resistor Essentials in the Power System



Comparative of Transformer Neutral Voltage Ranges

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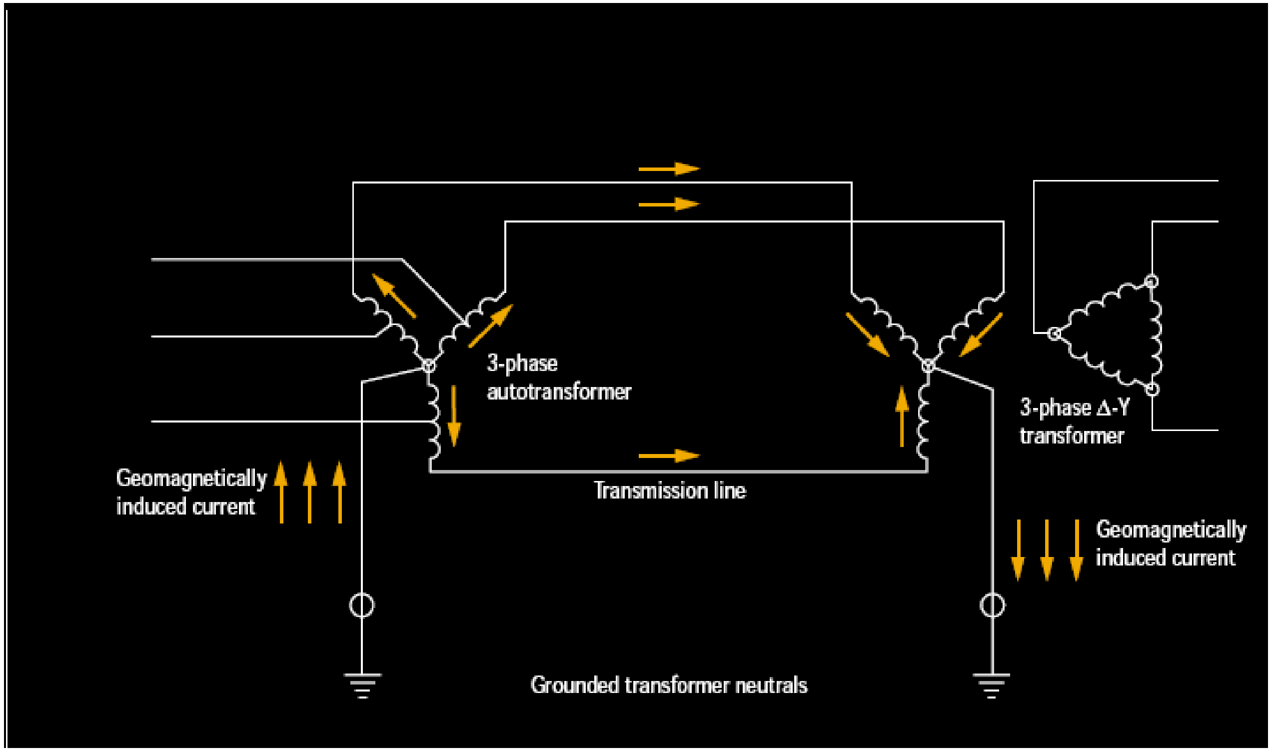
Device Attributes

- Near short circuit state for voltages above the range of application; upper interval consistent with ground fault neutral voltage levels and adequate protective margins to attendant neutral insulation levels

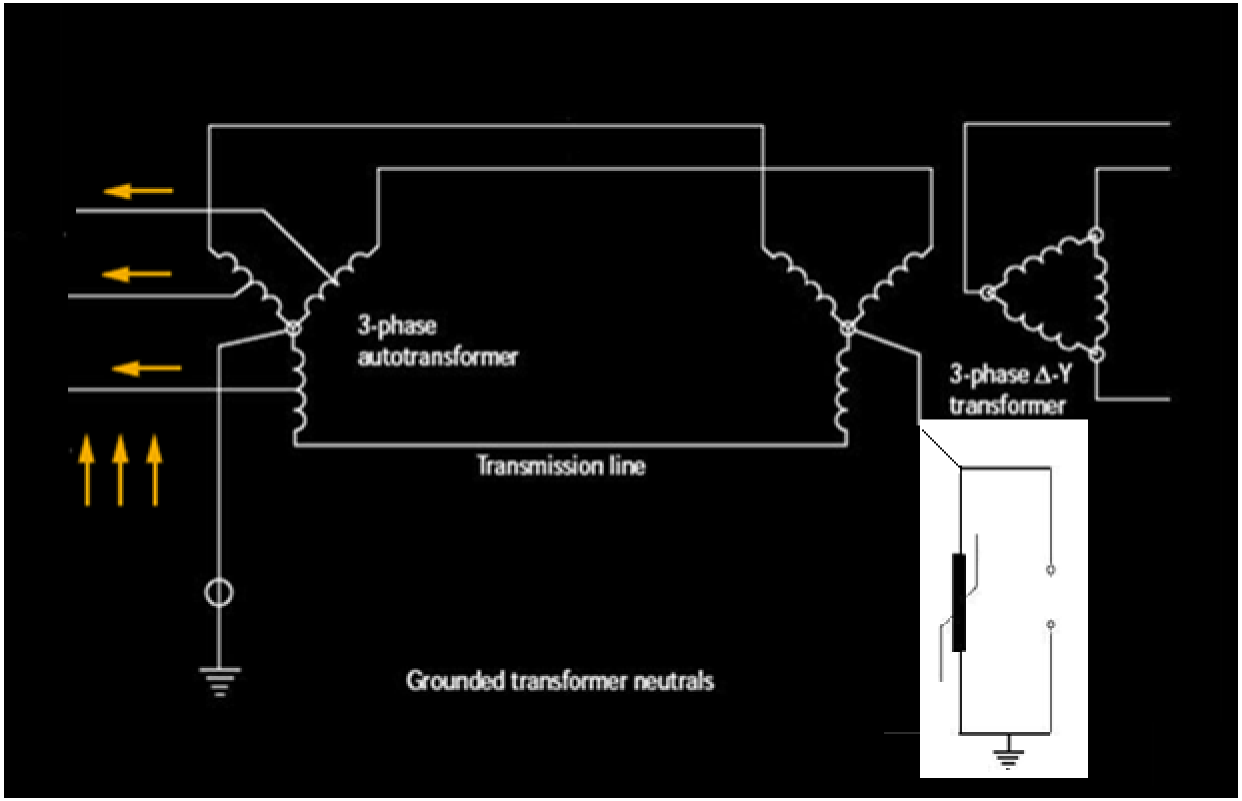
- Near open circuit state voltages below the range of application; lower interval consistent with GMD-induced neutral voltage levels

- Viable in-between interval of surge arrester ratings can be defined to be distinct, discernible, and satisfactorily ample for a practical set of GMD-mitigation conditions, fault criteria and ground residuals

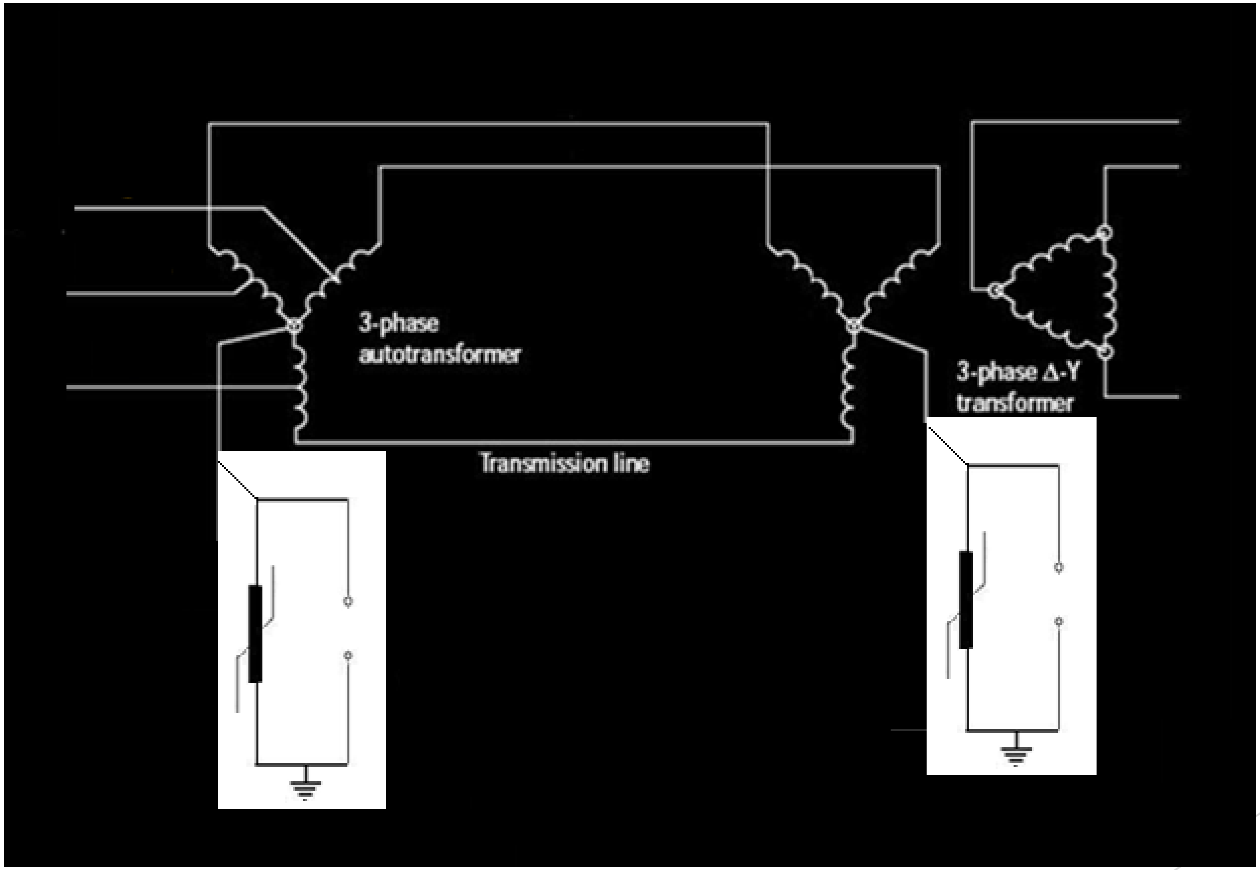
Typical GIC current circuit



Device Simple Circuit Insertion



Device Combined Circuit Insertion



Key Objective

Minimal Disruption/Impact on Pre-existing Power System Plant and Operation

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Comprehensive Study

Required exhaustive screening of design conditions to gain further understanding on all key aspects associated to this implementation

Comprehensive Study

Paper A2-110 CIGRE - Paris 2014

"Addressing Ground-Induced-Current (GIC) Transformer Protection"
Alberto Ramirez Orquin, Vanessa Ramirez

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Comprehensive Study

Computations performed with software based on models presented, discussed and validated via IEEE Transaction References:

1. *R. Achilles, A. Ramirez Orquin, Silicon Carbide Varistor Competitiveness in EHV Series Capacitor Reinsertion, IEEE Transactions on Power Systems, Vol. PWRS 1, pp. 127-34*

2. *A. Ramirez Orquin, R. Achilles, Modeling Series Capacitor Reinsertion in AC Studies, IEEE Transactions on Power Delivery, Vol. PWRD 4, pp. 1217-1222*

3. *A. Ramirez Orquin, R. Achilles, Ultra-High-Speed Relaying Protection: a Setting Methodology, IEEE Transactions on Power Delivery, Vol. PWRD 1, pp. 62-50*

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Comprehensive Study Software

Computer program features an accurate three-phase computation of system wide voltages and currents for any unbalance or fault condition. The mathematical solution enables a full nonlinear MOV (or Surge Arrester) model

Program interactive routine and output presents relay perspective i.e. the apparent Y/Z and ground current seen by relays at any local/remote substation such that the impact of GIC device on faulted-system pickup can be fully ascertained

Comprehensive Study:

Parametrical Range

KV Voltage Class: 220, 380, 500, 765

KV Arrester Ratings: 10, 15, 20

Ground-Current: 50 A to 30 KA

(over 600 cases run)

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Comprehensive Study:

Basic Outcomes

Neutral Currents on Tank

Neutral Potential Rise

Arrester Duty: Energy, Voltage

Comprehensive Study:

Typical Data

Autotransformer 500 MVA 230/500 KV
10 % short-circuit impedance
230 kV-Side rated current = 500/(√3x230) = 1256 A
SLGF Current = 12560 A
500 kV-Side rated current = 500/(√3x500) = 578 A
SLGF Current = 5780 A

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Comprehensive Study:

500KV Sample Results

500 KV	Without Device			With Device	
Max SLGF	6000	Amp		5850	Amp
Neutral Shift	0	KV		7.2	KV
Min SLGF	1000	Amp		981	Amp
Max Unbalance	300	Amp		297	Amp
Min Unbalance	50	Amp		49	Amp
GIC	200	Amp		30	Amp

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Comprehensive Study:

230KV Sample Results

230 KV	Without Device			With Device	
Max SLGF	13000	Amp		12769	Amp
Neutral Shift	0	KV		7.5	KV
Min SLGF	3000	Amp		2847	Amp
Max Unbalance	300	Amp		297	Amp
Min Unbalance	50	Amp		49	Amp
GIC	200	Amp		30	Amp

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Comprehensive Study:

Corroborations

Device solid performance with ample margins

Useful design optimization viable

Insightful findings regarding arrester/resistor energy sharing under ground currents

Low-ohmic resistors underperforming

Valuable compaction viable

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Device Basic Standards

IEEE 32 Standard for Neutral Grounding Devices
IEEE C62.92 Standard, Guide for the Application of Neutral Grounding
IEEE C62 1 IEEE Standard for Metal-Oxide Surge Arresters
IEEE 80 Guide for Safety in AC Substation Grounding
ANSI C2 NESC National Electrical Safety Code
ANSI C92 Alternating-Current Electrical Systems and Equipment
ANSI C37 High-Voltage Switches

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Device Design Considerations

Surge Arrester Normative of Application

IEEE Std. C62.11a™-2008 (Amendment to IEEE C62.11a™-2005) eliminates sub-clauses 8.16, 8.17 and 8.18 (*Pressure Relief*) replacing them with 8.21 whereas *Short Circuit Testing* is established instead. Short-Circuit Strength/Rating now appears in catalogs of top manufacturers.

Short-circuit ratings of ≥ 300 KA from as low as 5 KV arresters can be specified routinely. This guaranteed value renders typically a two thousand percent safety margin with respect to the fault a typical transformer neutral may ever see.

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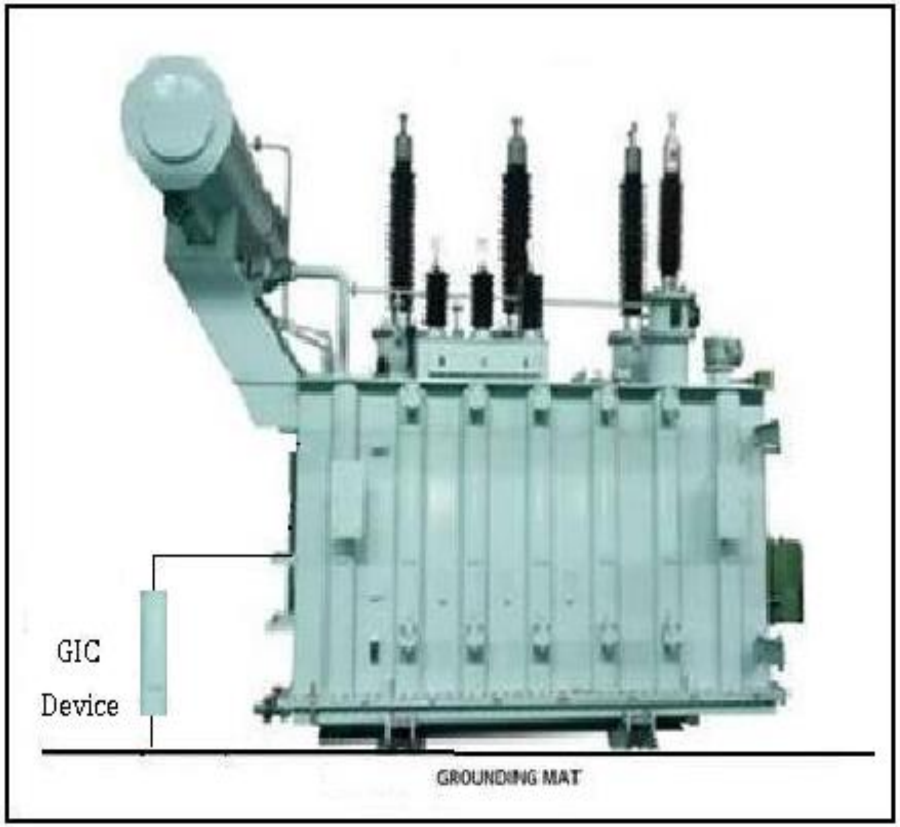
Device Physical Aspects - Footprint



Device Physical Aspects - Footprint

Minimal substation design impact

Minimal real state compromise

Minimal bay electrostatic dielectric compromise, components comprise few/small traditional 'electrodes'

Optimal one-device per transformer doable

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Device Attributes

- Two Patents Granted (2009-2011) by The United States Department of Commerce Patent and Trademark Office
- Two Patents Pending

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Device Concept Attributes

- Known Costs and Benefits
  (As required by NERC HILF Report-2010)
- Known Payees and Beneficiaries

Device Concept Attributes

- Cost-Effective hardening of autotransformers
- Cost-Effective hardening of GSU transformers
- Avoids costly and frequent Operational Procedures of totally unknown effectiveness

Resistive Neutral Grounding

Sole/exclusive endorsement by Public Document to a Commission of Congress, by the most renowned EMP/GMD specialists in the world, based on their 30 years of highly specialized experience

Resistor Neutral Grounding

Recommended to WH Office of Science and Technology Policy (OSTP) for Low-Frequency Threats Protection by top World Experts based on 30 years of Comprehensive US/International GMD Experience (2010)

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Resistor Neutral Grounding

EMP Commission Conclusively Recommended Congress the Primary and Generalized use of Grounding Resistors for Hardening/Mitigation (2010)

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Resistor Neutral Grounding

Ultimate concept acknowledgment: all device vendors, with no exception, offered the resistor GIC concept to the utility*

* Patent rights precluded those initiatives, constraining vendors to the capacitor option

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Dr. Alberto Ramirez Orquin – Principal

Dr. Ramirez Orquin has electric utility experience spanning over four decades, starting as a Niagara Mohawk Utility trainee, followed by five years as an application and research engineer at the General Electric Company/AC Transmission Engineering Operation in Schenectady, NY. He has practiced for several years in Canada, Brazil, Bolivia and Argentina where he notably served as Senior Advisor to the Secretary of Energy to conduct its National Grid Planning. As an IEEE Senior Member, he was distinguished at the institution's Centennial Meeting by the plenary T&D Committee for his leadership in the emblematical 500 KV Transmission Project of the Hidronor Company in Argentina. Furthermore, he had a key role as a co-author and general reviewer of the first edition of the EPRI/Edison Electric Institute's *EHV Transmission Line Reference Book 345 KV And Above* which has since become a world standard reference; likewise contributing to the books *Operation and Control of Electric Energy Processing Systems* (Wiley/IEEE 2010) as well as to the one sponsored by the Task Force on National and Homeland Security entitled *Apocalypse Unknown: the Struggle to Protect America from an Electromagnetic Pulse Catastrophe.* Additionally, he has extensively published Transactions and Journal Papers and holds several U.S. Patents on mitigation technology for grid security. In 2007, the U.S. Department of Homeland Security certified Dr. Ramirez Orquin as an Outstanding Researcher. Currently, he serves as a Member of NERC's Geomagnetic Disturbance Task Force serving in its Mitigation-Device Team, as well as a holding membership at Maine's PUC GMD-EMP Risk Working Group. Dr. Orquin currently teaches at the University of Puerto Rico.

He is a ME graduate of the Rensselaer Polytechnic Institute (RPI), and a Ph.D. graduate from the University of Texas (UTA).

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Vanessa Ramirez – Principal

Vanessa Ramirez has been involved in the energy sector for over twelve years with experience spanning from transmission interconnection studies, power system studies for power producers, ISO's, energy market analysis, and smart grid implementation in distribution systems at major US utilities. She was a Manager for The Structure Group for 8 years with smart grid assignments in the distribution automation and IT DMS areas; previously she had worked at Navigant consulting as a Senior Consultant were she participated in transmission asset analyses, FERC compliance, and transfer capacity/ interconnection access in the transmission systems; she has also worked at PB Power as an Engineer Consultant performing studies on grid congestion/pricing, congestion management, ancillary service functions, and reactive power assessment of deregulated markets performed through modeling of the system using different power tool applications.
She is the co-author of paper publications and two US patents, as well as the writer of several articles in energy and sustainability.
Mrs. Ramirez earned a Bachelor of Science in Electrical Engineering (EE) from the University of Mendoza, Argentina; and a Master of Science in Electrical Engineering from the University of Texas at Arlington (Summa Cum Laude). She is a Certified Energy Manager (CEM), and is affiliated to the IEEE and AEE (Association of Energy Engineers).

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Questions?

Thank you