Neutral blocking of Transformer GMD/GIC: why a Surge Arrester

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Audio Presentation

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General

Introducing a simple, cost-effective means to deal with this major hazard by means of an innovative surge-arrester GIC-blocking principle

Essential discussion regarding the impact upon transformer grounding of devices based on neutral GIC blocking

General

Key application to a typical Autotransformer

Significant invariance of the grounding ratios after a proposed arrester device deployment

Important revealed features set plausible benchmarking with alternative capacitive blocking devices

The Surge Arrester Protective Functionality

In addition to transformer and line protection surge arresters/(MOV) have been extensively utilized for series-capacitor protection

Transformer neutral-blocking devices use surge arresters for overvoltage protection

The Surge-Arrester Protective Functionality: its application to neutral-blocking devices

Exhaustive testing series performed at major high-power Labs

Full-scale testing series performed at major high-voltage Labs

Comprehensive simulations at both academic and industrial levels

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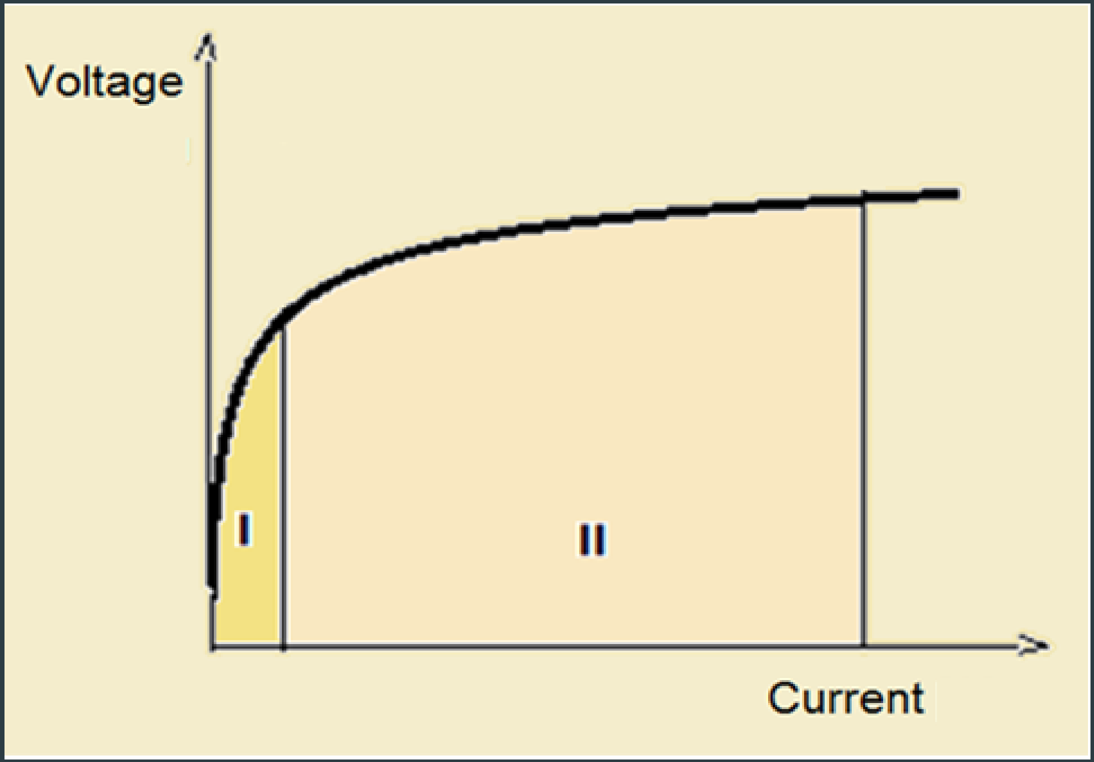
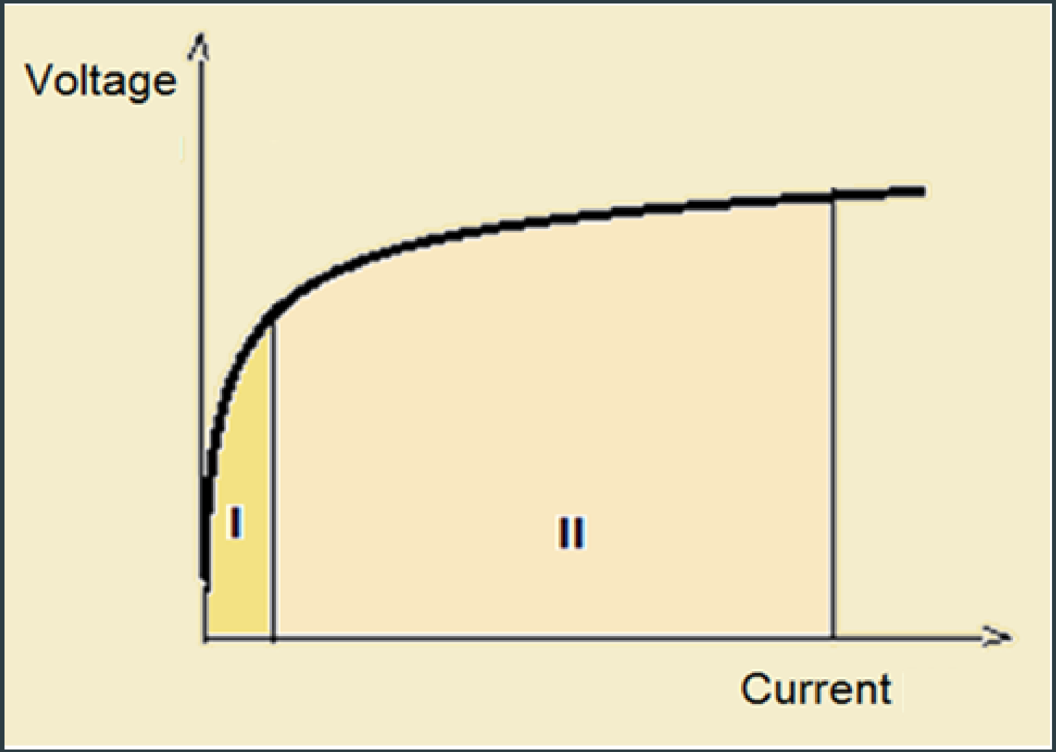
The Surge Arrester Dual Functionality



Ohm's Law applies to non-linear resistors; mind slopes at graph points of both Regions I and II

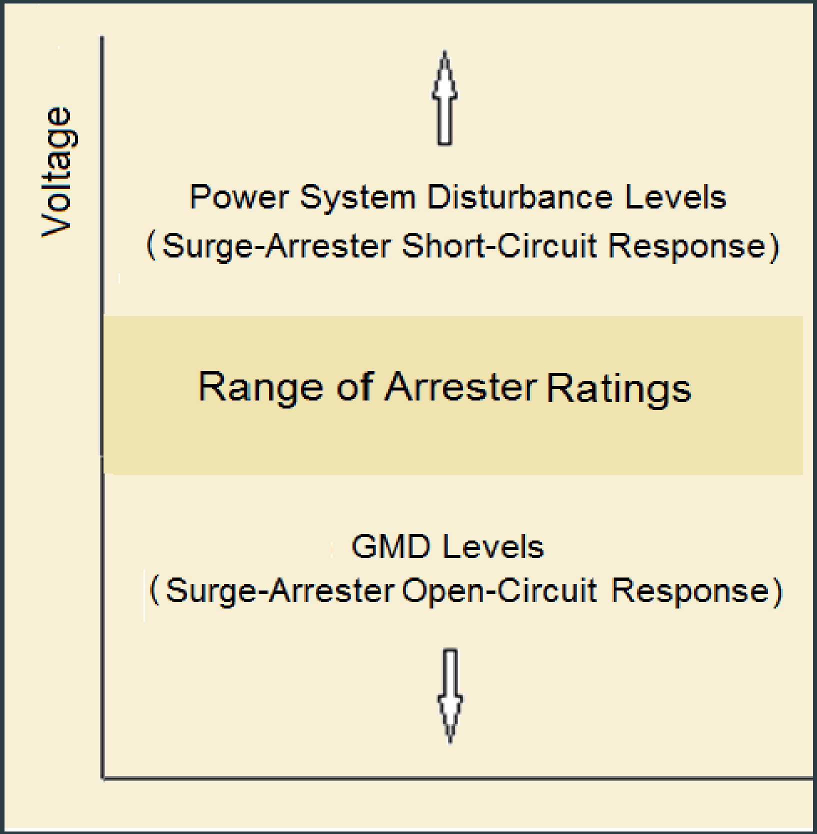
The Surge Arrester Dual Functionality



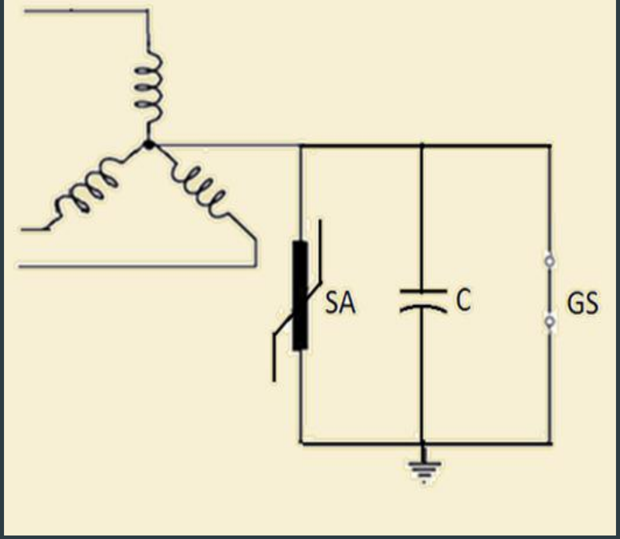
Region I: Resistance very high; consistent with GMD voltages

Region II: Resistance very low; consistent with ground-fault disturbances

Comparative of Transformer Neutral Voltage Ranges



Why a Neutral-Blocking Capacitor



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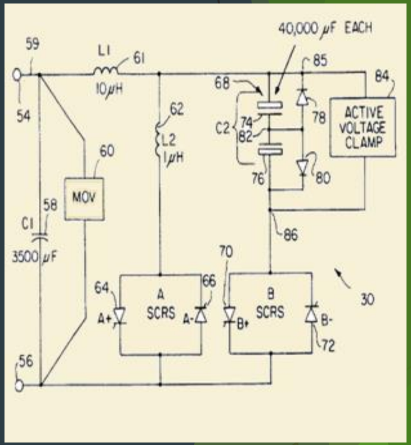
Why a Neutral-Blocking Capacitor

Industry reluctance to this approach is due to costs, size, complexity and perceived operational risks *

Understanding this problem, and its solution, starts with consideration of three power-system design states

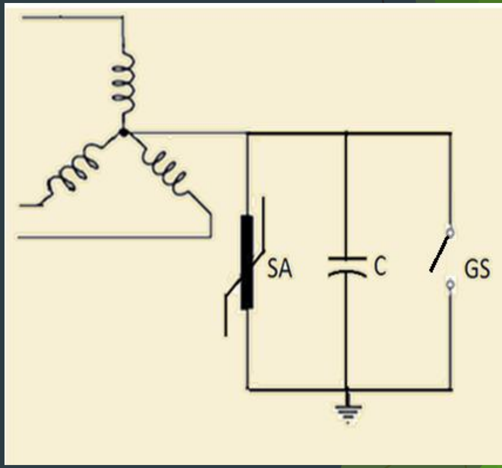


* Failure modes for the most part unknown

Neutral-Blocking Capacitor Facts

Neutral surge arrester protects the shunt capacitor bank from ground faults

Surge arrester also protects all components connected neutral-to-ground, including the winding neutral insulation to ground (typically 110 KV BIL)



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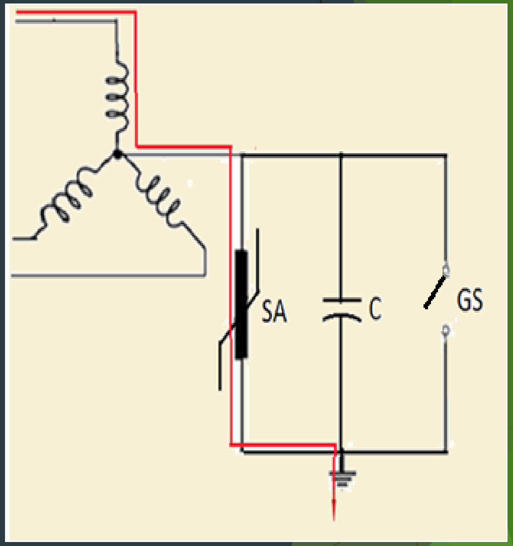
Neutral-Blocking Capacitor Facts

At ground faults surge arrester instantaneously by-passes the capacitor bank thus protecting the transformer wye winding by solidly grounding its neutral

Any perceived neutral-grounding capacitor function hence rendered unnecessary



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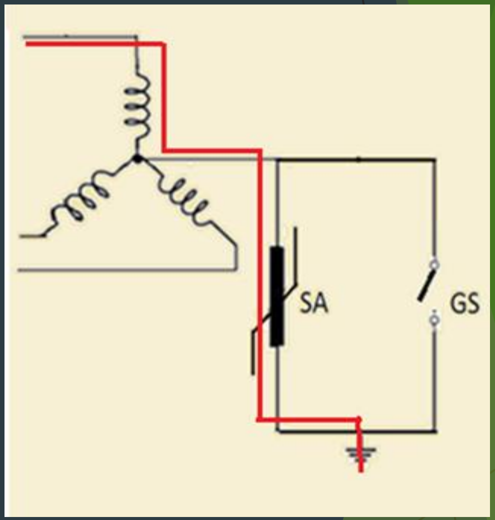
Neutral-Blocking Capacitor Facts

Through a ground fault, surge arrester does fully protect transformer winding neutral end, besides solidly grounding it after a few milliseconds from fault inception; with or without a shunt capacitor

Significant electric utility practice on grid transformer ungrounded wye design, with neutral surge arrester applications, feasible even in that substantially more demanding steady-state operation



Basic Power-system device design states

Three basic power-system device design states to consider, possibly in combination:

a) Ground-Fault Disturbances

b) GMD/GIC

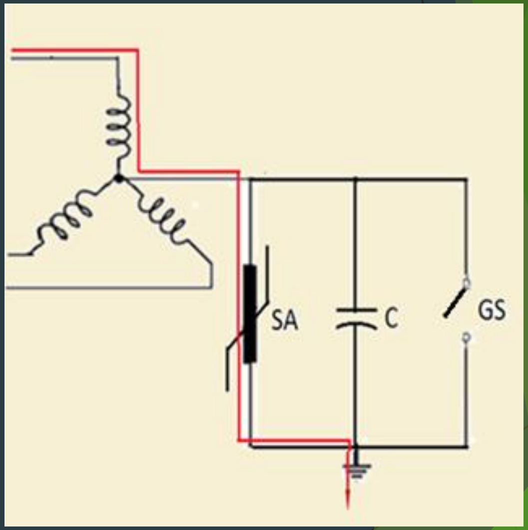
c) Steady State

Simultaneous Condition

Ground Fault and GMD/GIC

Mitigation Device Deployed

Inconsequential; transformer protected by Surge Arrester



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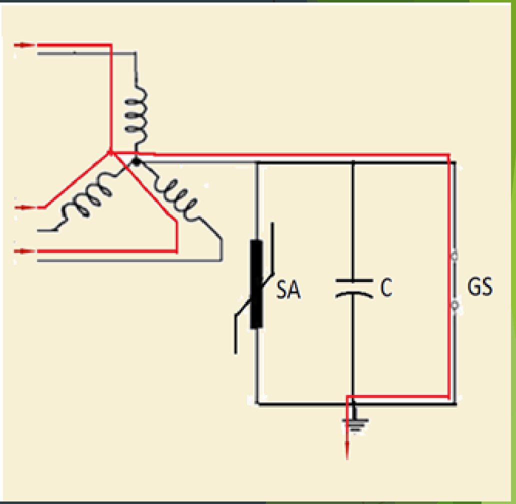
GIC-State Condition

Steady State and GMD/GIC

Mitigation Device Not Deployed

Problematic; transformer traversed by GIC currents



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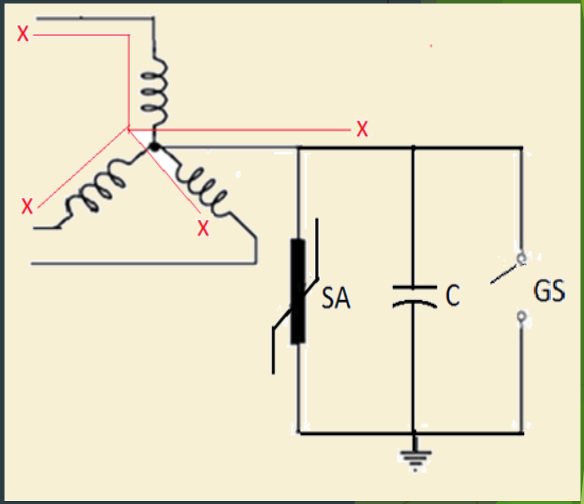
Why a Neutral-Blocking Capacitor

GMD/GIC Disturbance

Mitigation Device Deployed

Inconsequential; transformer protected by a neutral-blocking scheme



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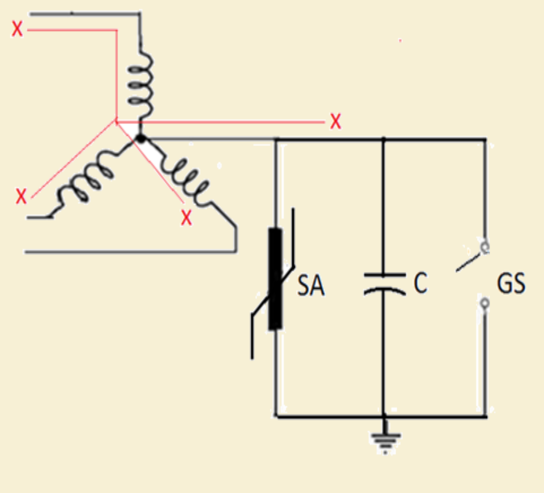
Why a GIC Neutral-Blocking Surge Arrester

GMD/GIC Disturbance

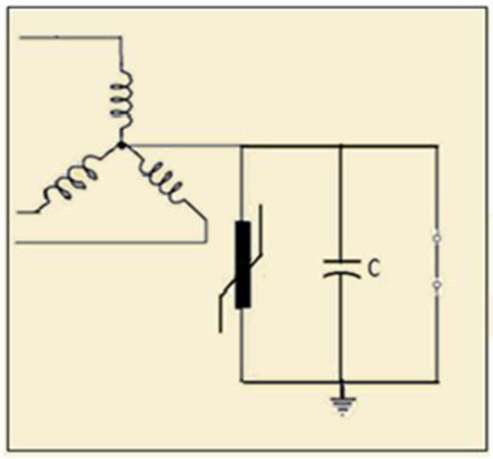
Surge arrester, in parallel with capacitor, performs a not duly appreciated blocking function identical to the one carried out by the capacitor

Otherwise GIC current could flow to ground through surge-arrester path

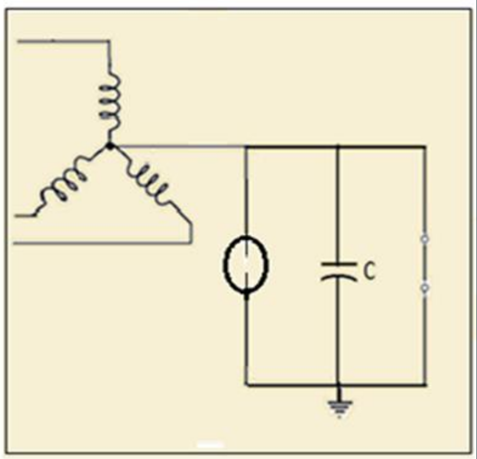


Actually, there is a record of that problem happening in a well-documented case

Capacitor Scheme Alternatives

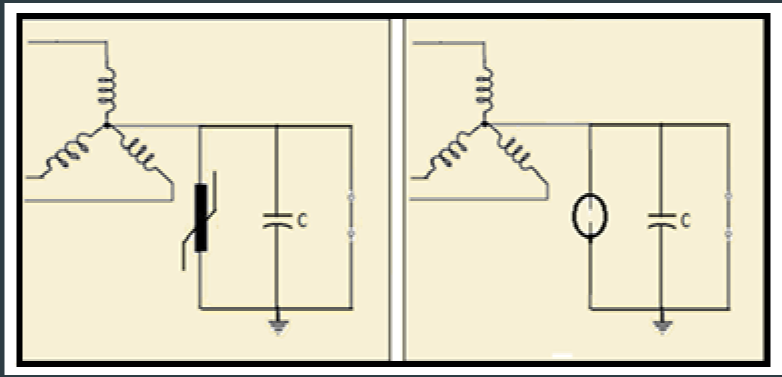


Capacitor Neutral-Blocking Device



Alternative Capacitor Device

Critical Considerations



Capacitor-bank footprint/rating, a limiting factor

Capacitor-bank constrained to Distribution lower-voltage ratings

Protective devices consequently constrained to Distribution lower-voltage ratings

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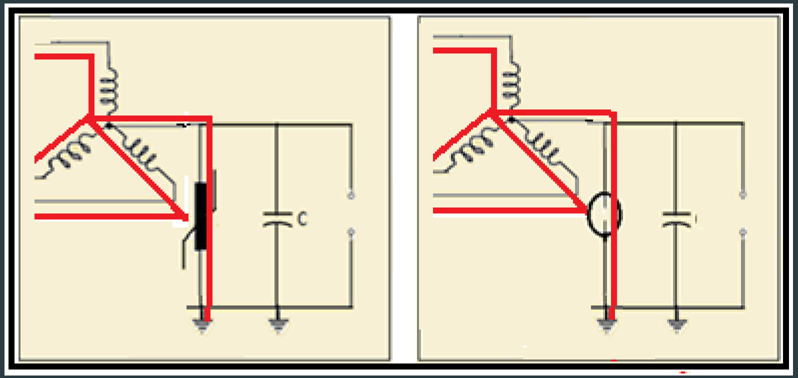
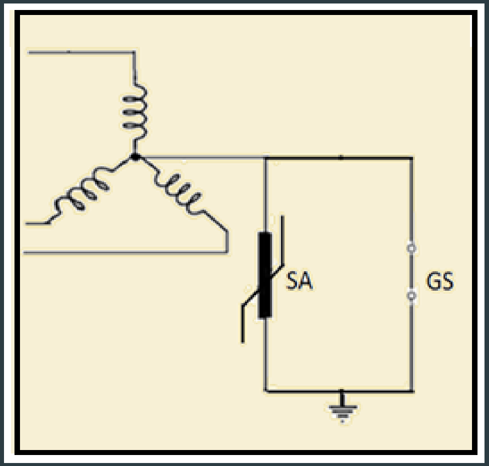
Critical Considerations



As protective devices are constrained to Distribution lower-voltage ratings a sizable EMP impact will set a neutral voltage causing either a surge arrester bypass to ground or alternatively conduction of the spark gap

GIC will then flow through the transformer to ground

Critical Considerations

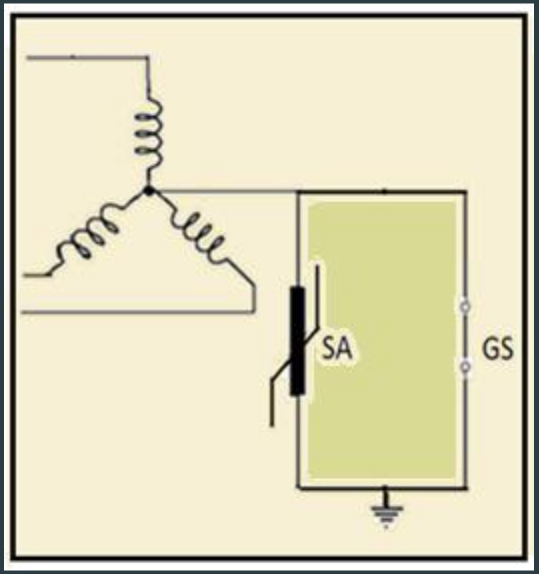


The only constraint upon a single Surge-arrester device stems from its dual-functionality requirements

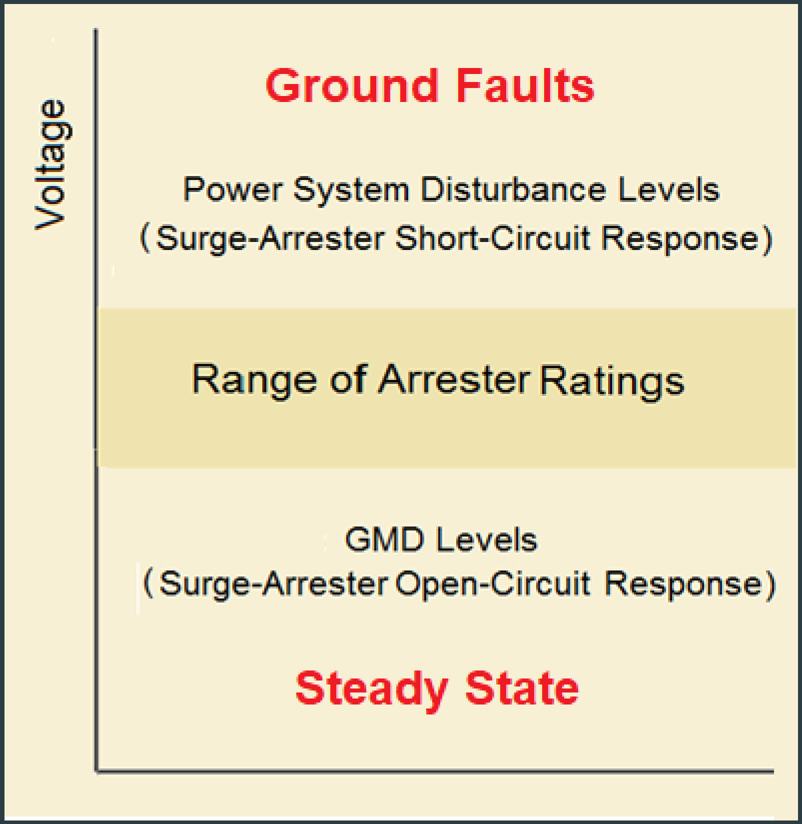
Much higher ratings possible making EMP neutral voltage inductions inconsequential to GIC blocking

Why a GIC Neutral-blocking Surge Arrester

We Propose



Surge Arrester: an adaptive Transformer Neutral-grounding



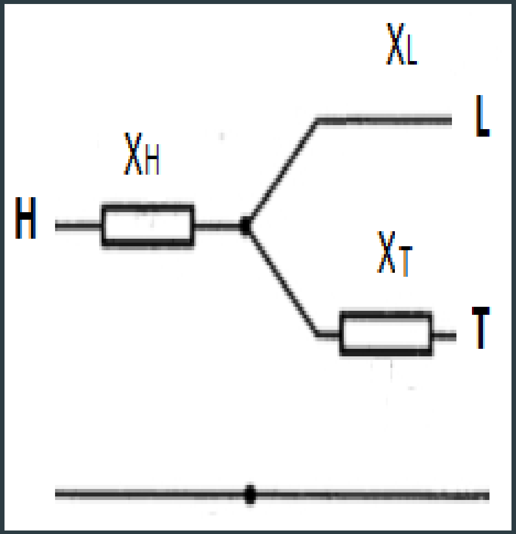
Steady-state: Arrester-device deployment analysis

Typical Transformer apparatus:

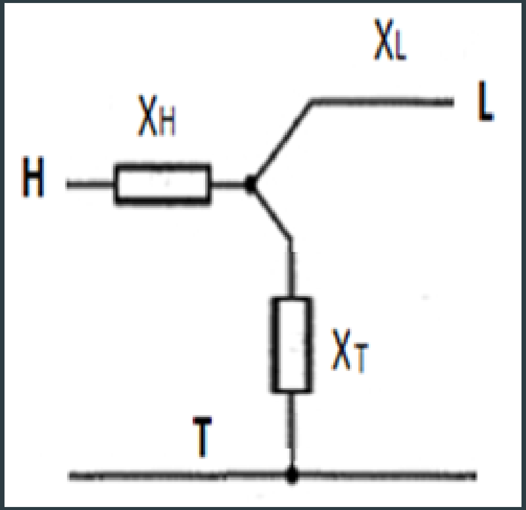
- Three-winding grounded Wye-Wye-Delta Autotransformer
- Two-winding Delta-Wye (grounded) GSU

Normal Steady-State Conditions

Typical three-winding Autotransformer



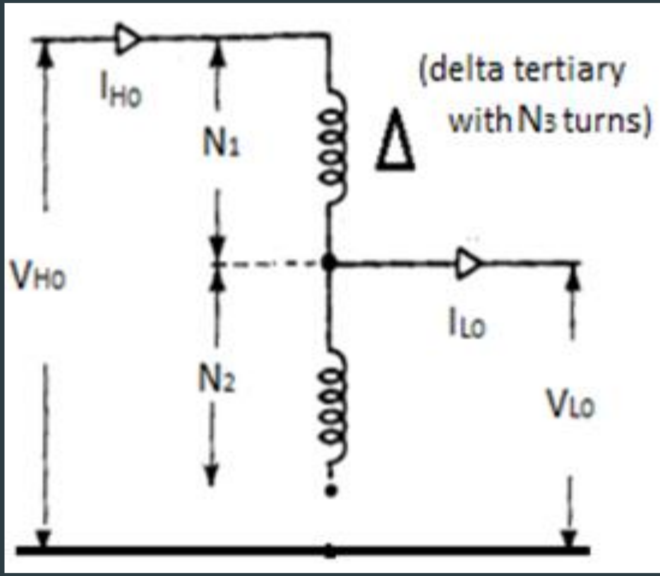
Positive/negative sequence per-unit equivalent circuit



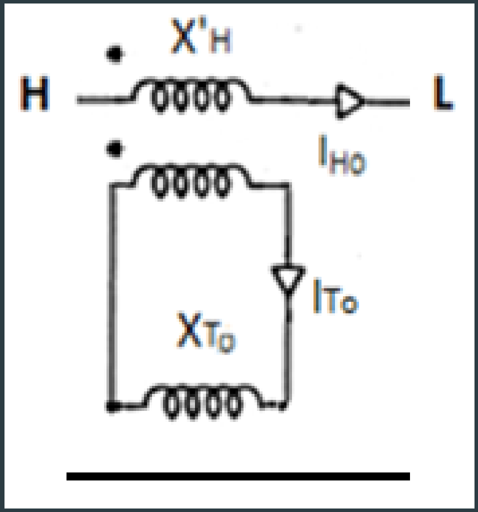
Zero-sequence per-unit equivalent circuit

Normal Steady-State conditions: Neutral Device deployed

Three-winding Autotransformer



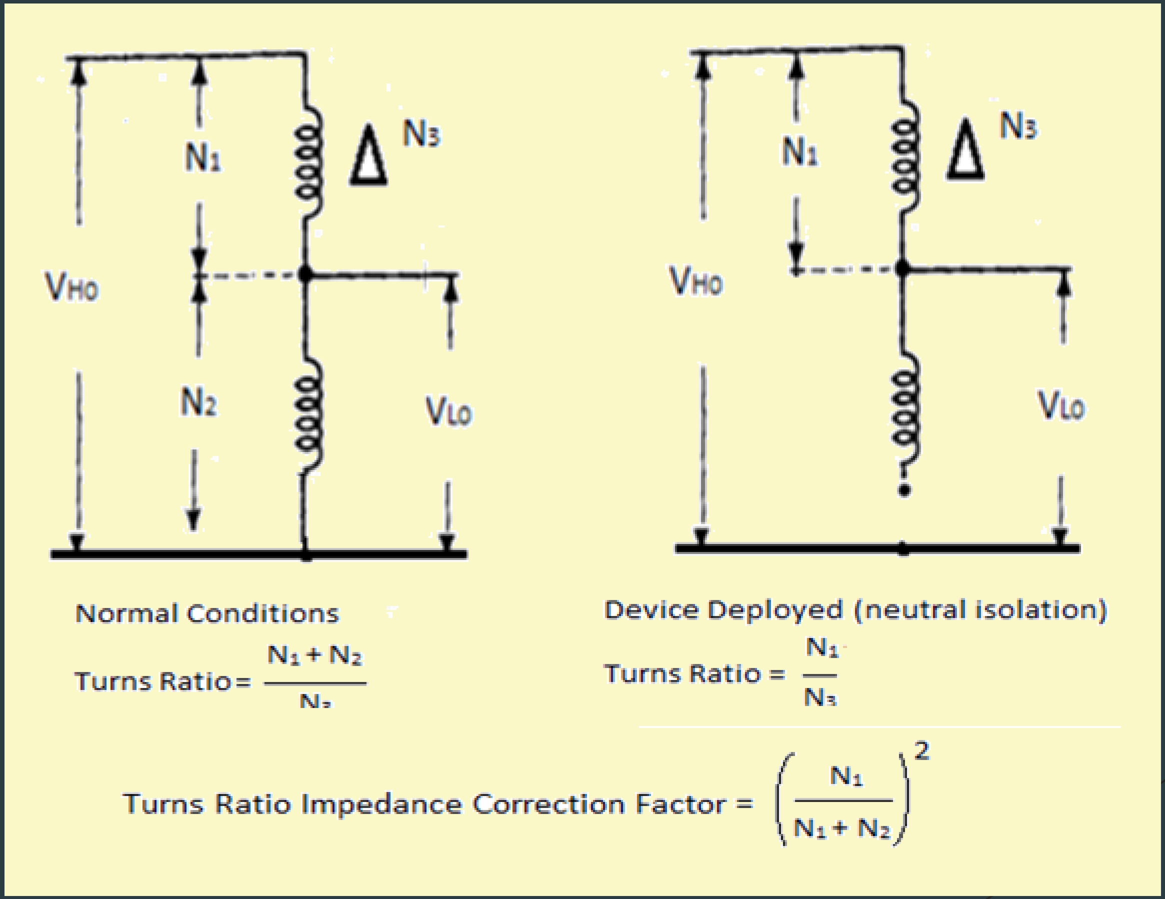
One-line diagram of device-caused neutral-to-ground isolation: zero-sequence flow



Zero-sequence circuit with neutral isolated from ground

Steady-State Performance

High-to-Tertiary Turns-ratios / Correction factor before and after arrester deployment (causing zero-sequence neutral-to-ground isolation)



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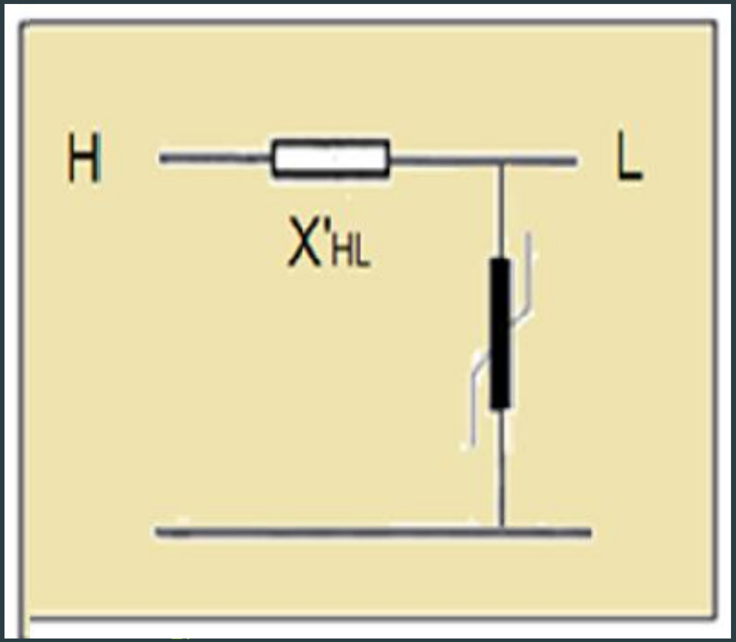
Zero-Sequence Equivalent after Device Deployment

Three-winding Autotransformer



Steady-state Performance

Three-winding Autotransformer

No significant change happens in the Grounding Coefficient after neutral arrester is deployed

Mitigating Geomagnetic Induced Currents Using Surge Arresters; INMR World Conference, Germany, October 2015

Steady-state Performance

GSU Transformer

Zero-sequence components typically negligible

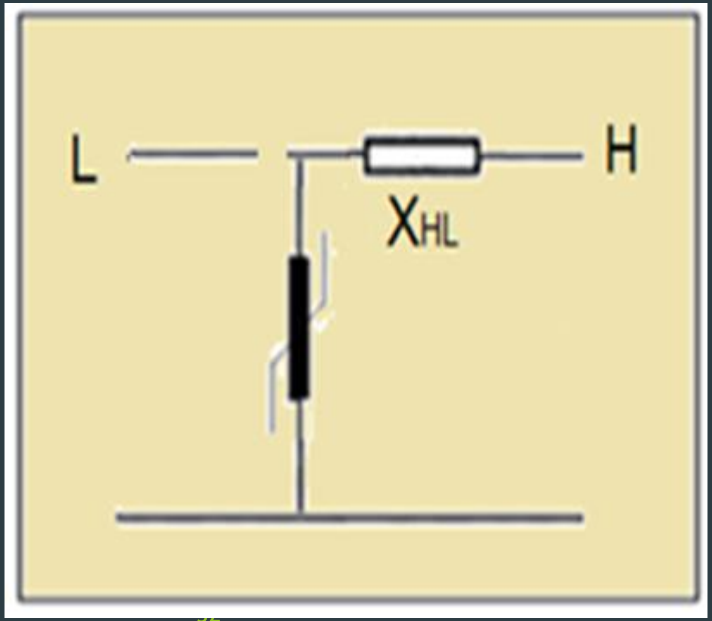
Neutral shift would be limited to a Ferranti-rise in the zero-sequence network

Zero-sequence flow through GSU immaterial as it refers to a line-end apparatus

Arrester device lends itself to a straight-forward specification from the unbalance examination

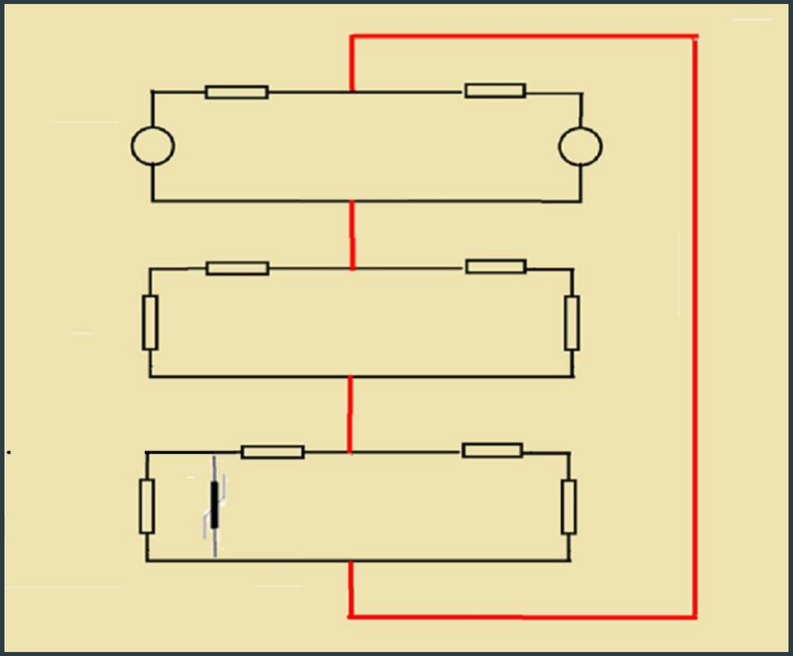
Zero-Sequence Equivalent after Device Deployment

GSU Transformer



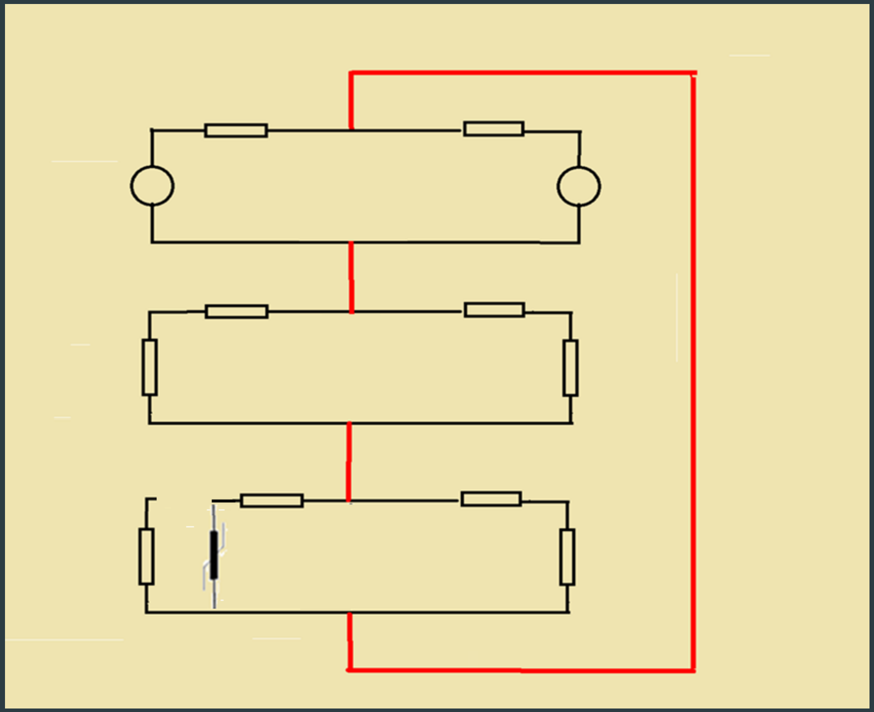
Symmetrical Component Equivalent Circuit for SLGF

Three-winding Autotransformer



Symmetrical Component Equivalent Circuit for SLGF

GSU Transformer



Conclusions

Steady-state performance, parametrical invariance, GIC blocking, ground-faults, zero-sequence current residuals, etc, the standalone surge-arrester device compares favorably with the one based on a capacitor bank, yet without any of its undeniable inherent risks

The difference can only be found at the blocking-function means: one performed by a capacitor bank and another by a common surge arrester

Conclusions

Proposed Technology enables a drastic cost and footprint reduction of mitigation devices as well as a foremost simplicity

Final Thoughts

Legitimate reservations regarding the incremental cost/benefit of adding massive capacitor-bank assemblies, with convoluted ancillaries, merely to secure the flow of inconsequential, quasi-parasitic, ground currents associated to a few GSU transformers at limited and short steady-state situations

Future/Ongoing Work

R&D on actionable early sensing of EMP shock waves (presently in advanced testing state)

R&D to favorably address the challenging issue of GIC current interruption

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Questions ?

Feel free to contact us and/or also to request a personal presentation of this material for an in-depth discussion

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