MITIGATING GEOMAGNETIC INDUCED CURRENTS USING SURGE ARRESTERS

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General

Introducing a simple, cost-effective, means to deal with this hazard

Innovative surge-arrester GIC blocking principle

Essential discussion regarding the impact of transformer grounding parameters of neutral blocking devices

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General

Application to transmission grid (auto)-transformer apparatus of typical design

Significant invariance of the applicable grounding ratios after arrester device deployment

Important revealed features set a plausible benchmarking with capacitive blocking devices

The Surge-arrester Protective Functionality

In addition to transformer and line protection, arresters and particularly MOVs have been extensively utilized for series capacitor protection

Most transformer neutral blocking devices use surge arresters for transformer winding neutral-end protection

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The Surge-arrester Protective Functionality

The metal-oxide non-linear resistor has been a well-established technology component for over half a century

Use has seen a wide spectrum of electric utility applications, mainly at the transmission and distribution levels

The Surge-arrester Protective Functionality

Wealth of references addressing transformer neutral protection

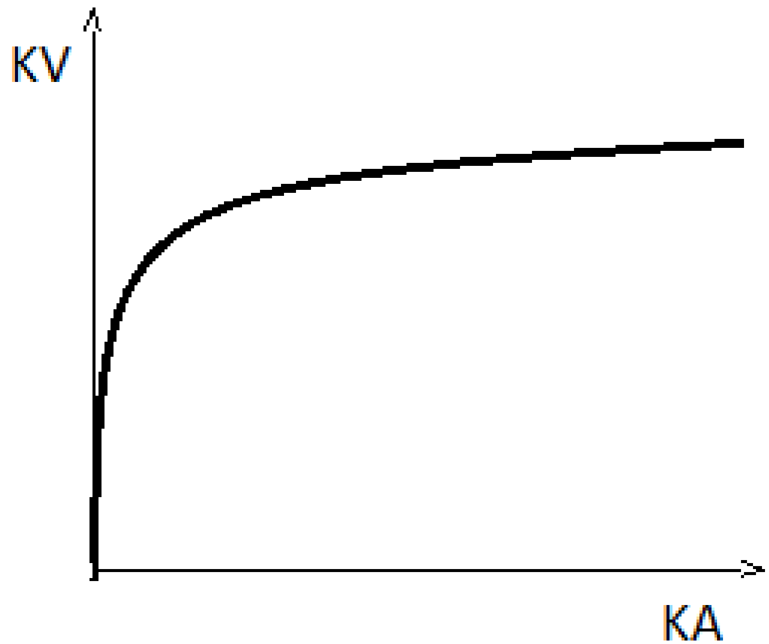
Exhaustive series of tests performed at major high-power labs

Comprehensive tests series performed at major research labs

Extensive simulations performed at the academic level

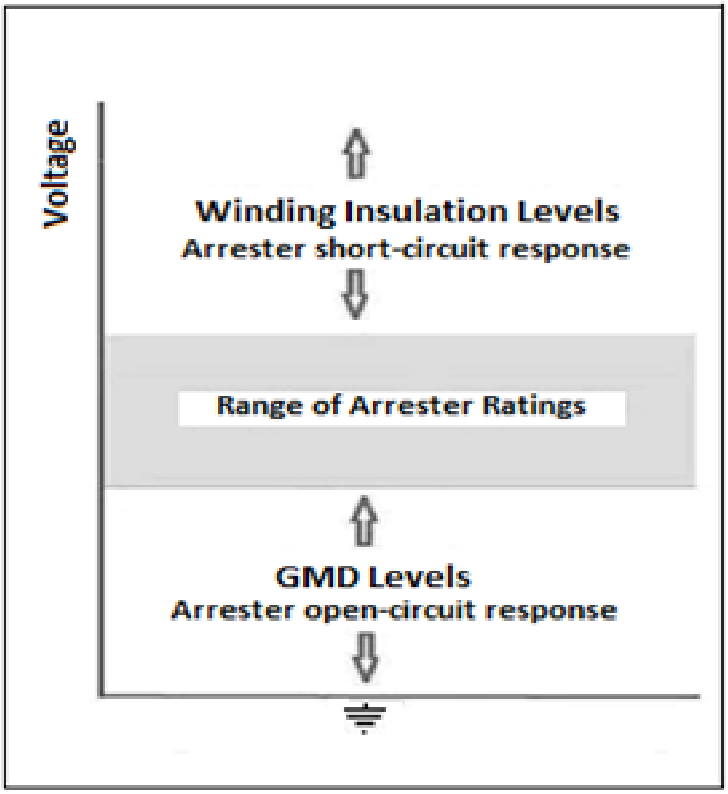
Electric Utility experience

The Surge Arrester GIC-Blocking Functionality

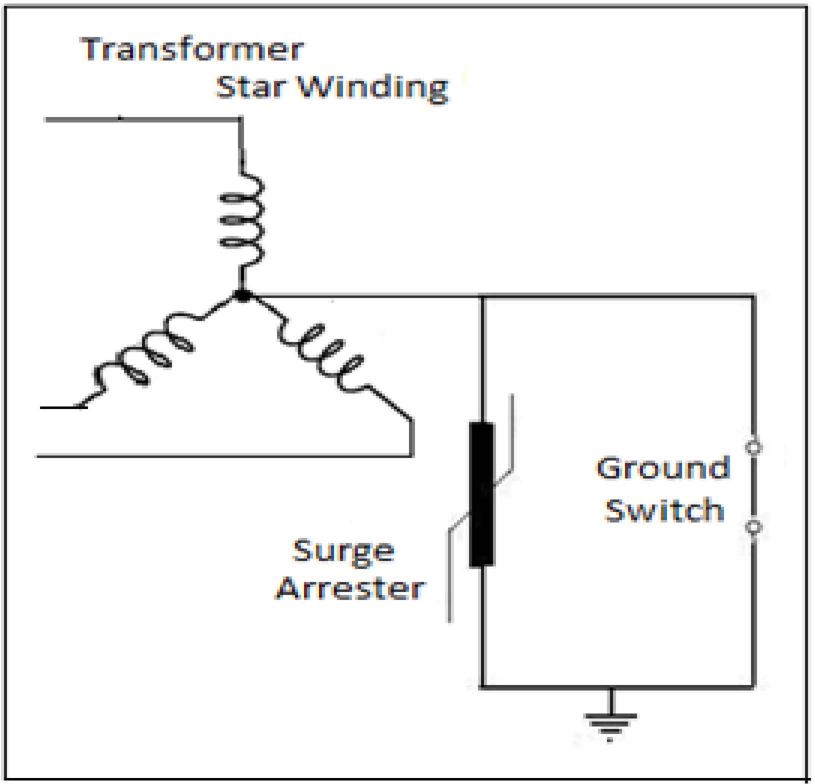


Ohm's Law applied to a non-linear resistor

Comparative of Transformer Neutral Voltage Ranges



Surge-Arrester GMD Mitigation Device



Steady-State Performance

Impact upon all AC steady-state variables

Impact upon grounding ratio X_0/X_1

Steady-State Performance

Transformer apparatus basic characteristics

Three-winding grounded Wye-Wye-Delta Autotransformer

Two-winding Delta-Wye (grounded) GSU apparatus

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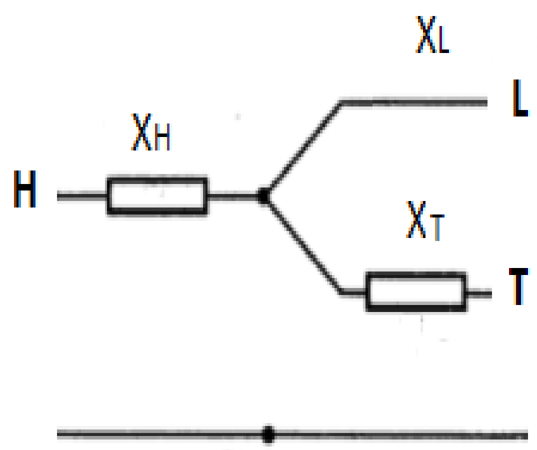
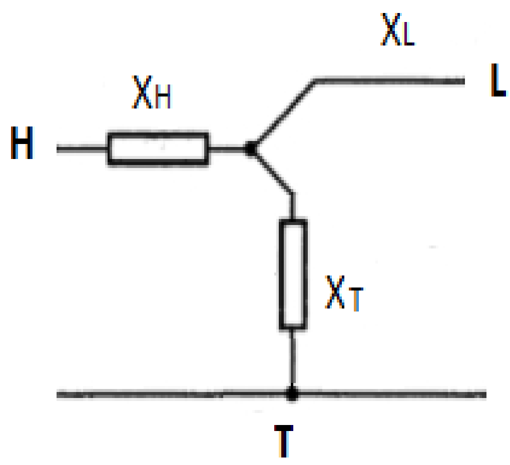
Three-winding Autotransformer



Positive/negative sequence per-unit equivalent circuit



Zero-sequence per-unit equivalent circuit

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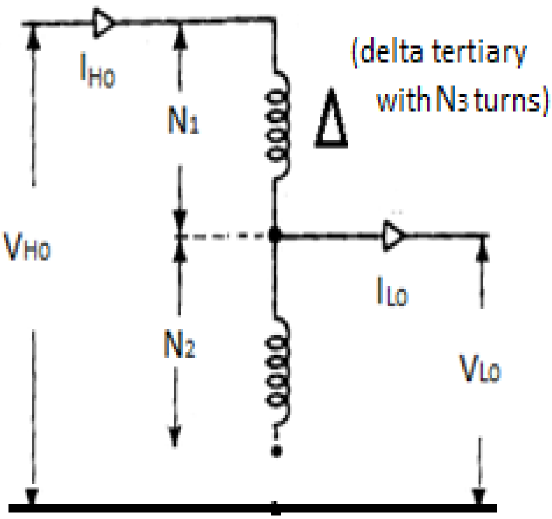
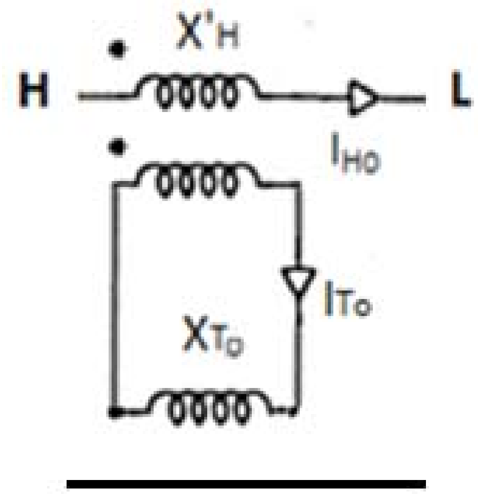
Three-winding Autotransformer



One-line diagram depicting isolation from neutral to ground: zero-sequence flow.



Zero-sequence circuit with neutral isolating from ground

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Steady-State Performance

Three-winding Autotransformer/Numerical Example

Grounding Coefficient before and after neutral arrester deployment

Nameplate 500/345/100 MVA 500/345/66 KV Grounded YYΔ Connection

X_{HL} = 0.10 pu on a 500 KV/500 MVA base

X_{HT} = 0.15 pu on a 500 KV/100 MVA base

X_{LT} = 0.13 pu on a 66 KV/100 MVA base

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Three-winding Autotransformer/Numerical Example

Grounding Coefficient before and after neutral arrester deployment

Conversion to 500 MVA base

X_{HL} = 0.10 pu

X_{HT} = 0.15 x 5 = 0.85 pu

X_{LT} = 0.13 x 5 = 0.75 pu

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Three-winding Autotransformer/Numerical Example

Grounding Coefficient before and after neutral arrester deployment

Windings reactance computation

$X_H = 0.5(X_{HL} + X_{HT} - X_{LT}) = 0.5(0.10 + 0.85 - 0.75) = 0.1$ pu

$X_L = 0.5(X_{HL} + X_{LT} - X_{HT}) = 0.5(0.10 + 0.75 - 0.85) = 0.0$ pu

$X_T = 0.5(X_{LT} + X_{HT} - X_{HL}) = 0.5(0.75 + 0.85 - 0.10) = 0.75$ pu

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Three-winding Autotransformer/Numerical Example

Grounding Coefficient before neutral arrester deployment

$$\frac{X_{HLzero\text{-}sequence}}{X_{HLpositive\text{-}sequence}} = 1.0$$

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Three-winding Autotransformer/Numerical Example

Grounding Coefficient after neutral arrester deployment

Turns-ratio correction factor $\dfrac{N_1^2}{(N_1+N_2)^2} = \dfrac{(500-345)^2}{(500)^2} = 0.1$

and the prevailing zero-sequence High-to-Low reactance becomes:

$$X'_{HT} = X_{HT} \dfrac{N_1^2}{(N_1+N_2)^2} = 0.85 \text{x}\ 0.1 = 0.085 \text{ pu}$$

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Three-winding Autotransformer/Numerical Example

Grounding Coefficient before neutral arrester deployment = 1.0

Grounding Coefficient after neutral arrester deployment = 0.085

Steady-State Performance

GSU Transformer

No zero-sequence flow may come from the generation side

Zero-sequence unbalance flow may develop from the transmission line side due to load or line-parameter unbalances

Steady-State Performance

GSU Transformer

Zero-sequence components typically negligible

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

Arrester device will basically see no real duty from this unbalance examination

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Conclusions

The metal-oxide surge arrester typically used for protection of power apparatus, in addition to being a component associated to most known GMD countermeasures, is proposed as the very sole element committed to suppress the undesired GIC flow through transformers.

Circuit diagram shows the basic arrangement of the scheme introduced, comprising a normally-closed transformer neutral-grounding switch, disposed in parallel with the surge arrester unit.

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Conclusions

Substantial independent research regarding the surge arrester suitability as a useful protective component of GIC mitigation schemes has been confirmed as reliable transformer neutral-insulation protective functionality when such a device gets deployed.

Presented technology and method entirely relieve the need for consideration of blocking mitigation components based on full-size power capacitors or linear-resistors

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Conclusions

Proposed technology allows for a drastic physical footprint minimization of mitigation devices.

Minimizing alternative frequent and onerous GMD-driven preventative operational procedures, mostly implying potentially problematic diversion/overburden of control centers

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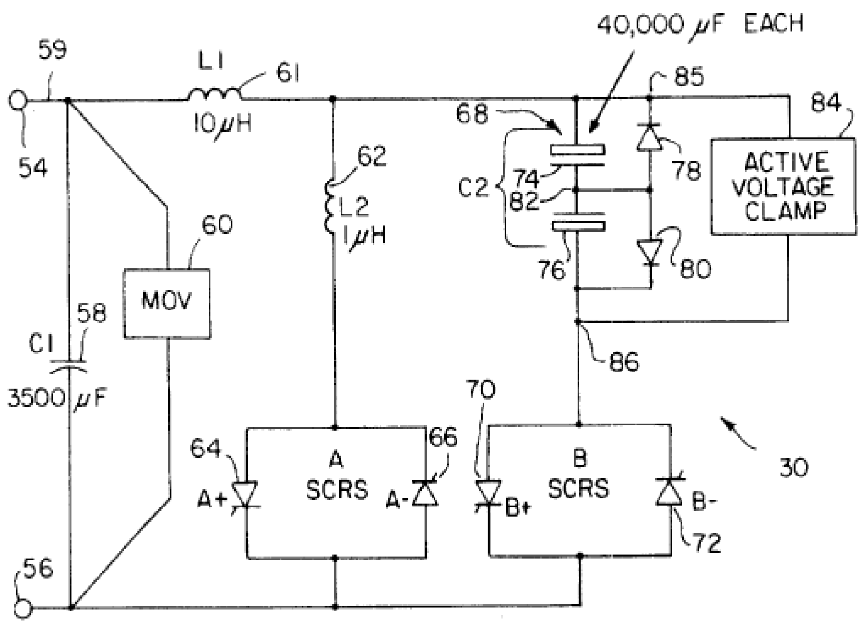
Conclusions

From a steady-state, current residuals, ground disturbances, parametrical invariance or GIC-blocking perspectives, the standalone arrester device compares favorably with the one based on the condenser, 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, the other by an arrester.

Conclusions



Capacitor Blocking Device

Arrester Blocking Device

Conclusions

Legitimate question about the incremental cost/benefit of adding massive capacitor banks merely to secure the flow of inconsequential, quasi-parasitic, ground currents associated to some GSU transformers.

Additional incremental cost/benefit questions stemming from the facts that any neutral-blocking unit would operate infrequently and able to reduce slightly about 50 percent of GIC on autotransformer apparatus.

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Future Work

Further/and on-going Research and Development on early sensing of EMP shock waves

Research and Development to address the issue of DC current interruption

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