Study Committee A2

Transformers

Paper A2_110_2014

Addressing Ground-Induced-Current (GIC) Transformer Protection

Alberto Ramirez Orquin, Vanessa Ramirez
UPRM/Resilient Grids

Motivation

- Electric utility industry under an imperative need to secure a cost-effective Geomagnetic Disturbance (GMD) mitigation device for power system transformers.
- Transformer protection from GMD, caused by natural solar magnetic activity or man-made EMP/E3.

General

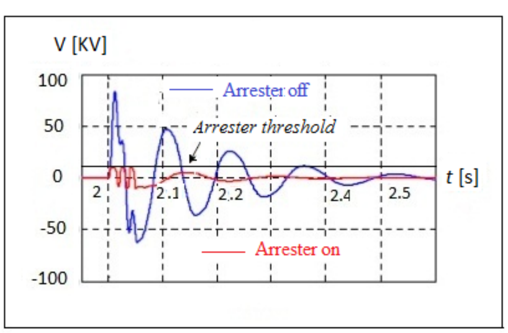
- Formulation is carried out in order to provide a useful GIC circuital blocking property.
- Analysis includes looking at the response of a non-linear resistive unit to GMD-originated voltage surges.
- A mitigation device concept is developed to provide a cost-effective reduction/blocking of harmful GIC flows through power transformers in the power grid.

Revisiting Non-linear Resistor Essentials in the Power System

- The non-linear resistor, either embodied 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.
- GIC functionality principle based on the non-linear resistor or surge arrester properties.

Non-linear Resistor Functionalities

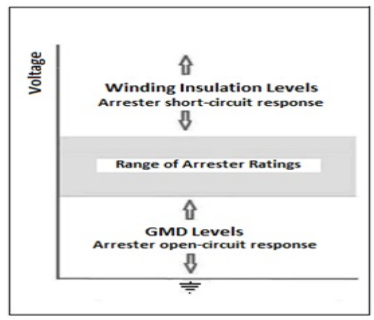
- Protective Functionality



1 - Typical SLGF Surge Arrester Neutral Voltage Protection

Non-linear Resistor Functionalities

- Blocking Functionality

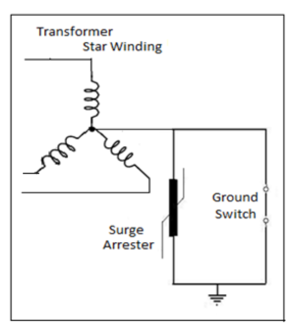


2 – Comparative of Transformer Neutral Voltage Ranges

Basic Rationale of Device Concept

- Device behaves as a near short-circuit condition with an equivalent very low resistance from transformer neutral to ground for voltages above the range of application.
- Device behaves as a near open-circuit condition with an equivalent very high resistance from transformer neutral to ground for voltages below the range of application.
- A viable interval of arrester rating applications can be found with a GIC-blocking functionality for both GMD and power system conditions.

Device Basic Scheme



3 – Basic Non-linear Resistor GMD Mitigation Device

Study Committee A2

Transformers

Paper A2_110_2014

Addressing Ground-Induced-Current (GIC) Transformer Protection continued

Device System Performance

- Evaluation study of the non-linear resistor GIC mitigation device performance carried out in order to ascertain its impact upon key operating contingencies from the electric power engineering perspective.

Methodology

- Three-phase AC-Study approach with specific software.
- Mathematical solution with internalization of a full nonlinear MOV/Surge Arrester model into the AC-Study platform.
- Computer program to calculate the protective relaying response i.e. the apparent impedance/admittance and ground currents seen by relays at any local/remote substation.

Scope

- SLGF, at apparatus primary and secondary voltage winding terminals, selected within the study criteria.
- Through-transformer maximum and minimum ground-fault cases run for winding-voltage levels associated to the 220, 380, 500 and 765 KV voltage classes respectively
- SLGF maximum and minimum levels computed with and without the GIC mitigation device in service; in addition, the neutral shift caused by such a device under fault conditions was also computed in every case.

Results Tabulation – Table 1

Transformer Neutral Voltage/Current under SLGF
(* indicates surge arrester inserted)

Transmission Voltage		765 KV			500 KV	
Arrester Rating [KV]	10	15	20	10	15	20
SLGFmax [A]	10000	10000	10000	10000	10000	10000
SLGFmax* [A]	9750	9626	9501	9619	9428	9238
Neutral Shift [V]	10999	16499	21999	11000	16499	21999
SLGFmin [A]	3000	3000	3000	3000	3000	3000
SLGFmin* [A]	2925	2887	2850	2885	2829	2771
Neutral Shift [V]	10999	16498	21996	10999	16498	2197

Results Tabulation – Table 2

Transformer Neutral Voltage/Current under SLGF
(* indicates surge arrester inserted)

Transmission Voltage		380 KV			220 KV	
Arrester Rating [KV]	10	15	20	10	15	20
SLGFmax [A]	16000	16000	16000	16000	16000	16000
SLGFmax* [A]	15198	14797	14395	14614	13921	13229
Neutral Shift [V]	10999	16500	21999	11000	16500	21999
SLGFmin [A]	5000	5000	5000	5000	5000	5000
SLGFmin* [A]	4749	4624	4499	4567	4350	4134
Neutral Shift [V]	11000	16499	21998	10999	16499	21998

Discussion of results

- Relative magnitude changes, due to arrester device insertion, in the range of 2.5 percent to 17 percent changes, between 2.5 and 8.7 percent for a 10 KV depending on voltage class and arrester rating
- Minimum arrester rating.
- Magnitudes shown, and depending on design values like transformer winding neutral BIL, relaying technology, etc. pose, for the most part and per se, no problems to the power system.
- Arrester mitigation device transitions, during SLGF, into a full bypass solid grounding.

Conclusion

- Major refinement to the classic GMD resistive mitigation device is presented.
- A novel feature of the surge arrester is revealed which provides transformer GMD protection.
- Arrester performance under ground ascertained for a comprehensive set of conditions.
- Arrester confirmed to substantially sustain a relative effective invariance of standardized power system grounding and relaying application values.
- A GMD mitigation device scheme is proposed not requiring the utilization of capacitors or resistors.
- Concept allows for a cost-effective technology.