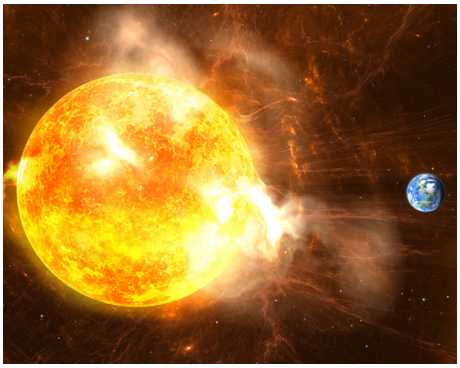
DOBLE CONSULTING & TESTING SERVICES

GEOMAGNETIC DISTURBANCE RISK MITIGATION

NERC TPL-007-1 Compliance



Large power transformers connected to the EHV transmission system may experience both winding and structural hot spot heating as a result of geomagnetic disturbances (GMDs). Severe GMDs caused by solar storms enter through the upper layers of our atmosphere and can induce currents in long conductors, such as power lines, on the Earth's surface. This could overload the electric grid system triggering voltage collapse - or worse - damage expensive extra-high voltage (EHV) power transformers. The primary impact on EHV power transformers is a result of the quasi-dc current that flows through wye-grounded transformer windings.

New NERC Standards to Address Geomagnetic Disturbance Events

Protecting the bulk electric system from the impact of GMDs is the focus of the new NERC standard TPL-007-1 with an enforcement date that began on January 1, 2017.

Utilities must conduct both initial and ongoing assessments of the potential impact of a "1-in-100-year" benchmark GMD event on their equipment and the bulk power system as a whole including:

- **GIC Disturbance Vulnerability Assessment** for a system's ability to withstand a benchmark GMD event without causing a wide area blackout, voltage collapse, or transformer damage. *Applicability: planning coordinators, transmission planners*
- **Transformer Thermal Impact Assessment** to ensure that all high-side, wye grounded >200kV transformers can withstand thermal transient effects associated with a benchmark GMD event. *Applicability: generation and transmission companies*

The standard also requires corrective action mitigation planning to protect against instability and cascading failures.

Doble Services for GMD Risk Mitigation

Doble's Professional Services team can perform a thermal impact engineering study to establish power transformer capabilities while under geomagnetic disturbances according to the IEEE C57.163-2015 Guide.

Doble is your trusted partner with extensive transformer design expertise at over 50 different transformer manufacturing factories across North America, South America, Europe & Asia Pacific. We have extensive experience with all major legacy manufacturers including GE, McGraw Edison and Westinghouse.

Interested in learning more?

Contact Doble today to learn more about this service or to keep informed and to share your approach to mitigating the effects of GMDs on large power transformers.

Impact of GMDs on Transformers

A geomagnetically-induced current (GIC) results in an offset of the ac sinusoidal flux in the transformer core. This results in asymmetric or half-cycle saturation, leading to a number of effects including:

- Increased exciting current and reactive power absorption
- Hot spot heating of non-current carrying metallic members due to stray flux
- Harmonics
- Increased vibration and noise level
- Hot spot heating of windings due to harmonics and stray flux

The transformer's reactive power absorption can cause power system instability and lead to unintended tripping further disturbing the system stability.

Thermal Impact Assessment Requirements

The effects of asymmetric or half-cycle saturation on EHV transformers are relatively well understood but difficult to quantify. Based on the benchmark GMD event, a transformer thermal impact assessment should contain the following analysis:

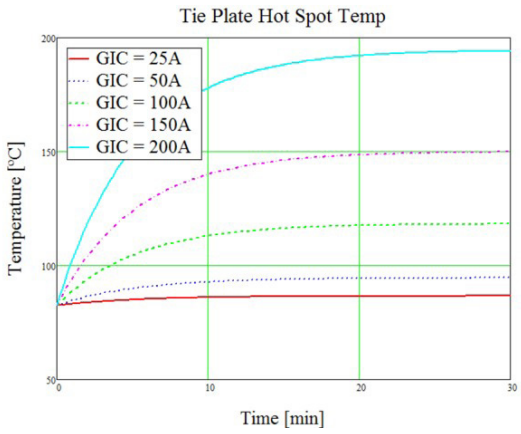
1. Calculation of transformer magnetizing current for the specified GIC currents
2. Calculation of peak magnetizing current as a function of GIC level
3. Calculation of reactive power consumed by the transformer as a function of GIC level
4. Calculation of harmonic components of magnetizing current due to GIC
5. Calculation of top clamp, tie plate and winding hotspot temperatures
6. Calculation of thermal capability curves for base and peak GIC levels

Thermal Impact Assessments on Service-Aged Transformers

Doble's Professional Services can perform an engineering study to establish power transformer capabilities while under GMDs according to the IEEE C57.163-2015 Guide. Deliverables include a final GIC capabilities report. Doble will perform the transformer thermal impact assessment based on 5 GIC levels defined by the client, resulting from the client's network system analysis.

Transformer information requirements provided by customer:

1. Basic Transformer Nameplate Data
2. GIC Duration Table
3. Transformer Core Data
4. Excitation Table
5. Magnetizing Winding Data
6. Clamping Data
7. Tie plate Data
8. Tank Data



Tie Plate Hot Spot During GIC

For more modern transformers, the majority of study input data may be obtained from design review documentation. On older transformers (>20 years) design review documentation may not be readily available. The original design information might be available in the marketplace from a new owner of the OEM information in some instances. In other cases, partial study input data can be extracted from test reports and outline drawings while the remaining input data would need to be approximated from sound engineering assumptions in alignment with the IEEE guide.

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