Temperature-Triggered Failure Hazard Mitigation of Transformers Subject to Geomagnetic Disturbances

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ABSTRACT
Geomagnetic disturbance (GMD) engenders significant threats to the power system infrastructures, potentially resulting in the bulk high-voltage power transformers half-cycle saturation, excessive system reactive power losses, and transformer over-healing, among others.

This research focuses on the mitigation of temperature-triggered transformer’s hazard of failure following a GMD disturbance. The main contributions of the paper are: a) deriving temperature models of transformers during a GMD hotspot and under full load conditions; b) quantifying the loss of life and failure risk of transformers triggered by a GMD disturbance; c) mitigating the transformer’s hazard of failure through reducing the loading of the transformer. The above approach is tested in the Texas 2000-bus synthetic case, and the results verify the effectiveness of the algorithm.

To implement the mitigation techniques on failure hazard of transformers, groups of critical transformers across the system are identified based on the GIC injection variation and their corresponding temperature rise. In so doing, we prioritize the vulnerable transformers within the critical cluster of transformers, i.e., those with highest failure probability and system-wide consequences.

2003 U.S. - CA GMD- CAUSED BLACKOUT

3128 Affected 1.6 million people in and near 65 villages within eight U.S. states.

GIC MODELING AND ITS CHARACTERISTICS

KEY PARAMETERS FOR GIC CHARACTERIZATION

• High-altitude areas are more susceptible to the GIC hazards.
• GICs magnitude are more vulnerable while they are flowing through high-voltage lines.

TRANSFORMER THERMAL MODEL

IDENTIFICATION OF MOST VULNERABLE TRANSFORMERS

MITIGATION PROCEDURES ON THE MOST VULNERABLE TRANSFORMERS

Algorithm:
1. Solve GIC flow
2. Calculate the transformer’s GIC-caused temperature rise (θt (θt)) and the hotspot temperature under loading condition (θt = θt)
3. Identify the overloaded transformers
4. Calculate the loss of life of transformers and hazard of failure (H(θc, θt))

Hazard Mitigation Procedure
5. Set the desired threshold for hazard rate as Hθt
6. Initialize the transformer load rate, line portion (flow, load shed step rate, simulation time, etc)
7. while θt > θt & (Load- load shed)\[0\]
8. Reduce the Load(θc, θt) by step size
9. Perform recursive step 2 (θt (θt)) & step 4 (H(θc, θt))
10. end procedure

The hazard rate is a function of temperature, which itself is a function of current, one way to reduce the hazard rate is to shed the load of high-risk transformers.

REFERENCE