NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Geomagnetic Disturbance Operating Procedure Template

Transmission Operator

Overview

Operating procedures are the quickest way to put in place actions that can mitigate the adverse effects of geomagnetically induced currents (GIC) on system reliability. They also have the merit of being relatively easy to change as new information and understanding concerning this threat becomes available. Operating procedures need to be easily understood by, and provide clear direction to, operating personnel. This is especially true since most operators are unlikely to frequently respond to significant GMD events.

Some actions listed below should only be undertaken if supported by an adequate GIC impact study and/or if adequate monitoring systems are available. Otherwise they can make matters worse. Those actions are indicated by the phrase "if supported by studies".

Determining that a geomagnetic disturbance (GMD) is significant enough to warrant the initiation of special operating procedure(s) depends on the geographical location of the power system/equipment in question coincident with the location of the GMD measurement and forecast. Amount of advance notice obviously factor heavily in what specific actions can and should be taken. Note these are recommended actions; specific actions may vary by system configuration, system design and geographic location of the entity.

Information and Indications

The following are triggers that could be used to initiate operator action:

- External:
  - NOAA Space Weather Prediction Center or other organization issues:
    - Geomagnetic storm Watch (1-3 day lead time)
    - Geomagnetic storm Warning (as early as 15-60 minutes before a storm, and updated as solar storm characteristics change)
    - Geomagnetic storm Alert (current geomagnetic conditions updated as k-index thresholds are crossed)
- Internal:
  - System-wide:
    - Reactive power reserves
    - System voltage/MVAR swings/current harmonics
  - Equipment-level:

- GIC measuring devices
- Abnormal temperature rise (hot-spot) and/or sudden significant gassing (where on-line DGA available) in transformers
- System or equipment relay action (e.g., capacitor bank tripping)

Actions Available to the Operator

The following are possible actions for Transmission Operators based on available lead-time:

Long lead-time (1-3 days in advance, storm possible)

1. Increase situational awareness
    a. Assess readiness of black start generators and cranking paths
    b. Notify field personnel as necessary of the potential need to report to individual substations for on-site monitoring (if not available via SCADA/EMS)
2. Safe system posturing (only if supported by study; allows equipment such as transformers and SVCs to tolerate increase reactive/harmonic loading; reduces transformer operating temperature, allowing additional temperature rise from core saturation; prepares for contingency of possible loss of transmission capacity)
    a. Return outaged equipment to service (especially series capacitors where installed)
    b. Delay planned outages
    c. Remove shunt reactors
    d. Modify protective relay settings based on predetermined harmonic data corresponding to different levels of GIC (provided by transformer manufacturer).

Day-of-event (hours in advance, storm imminent):

1. Increase situational awareness
    a. Monitor reactive reserve
    b. Monitor for unusual voltage, MVAR swings, and/or current harmonics
    c. Monitor for abnormal temperature rise/noise/dissolved gas in transformers[1]
    d. Monitor geomagnetically induced current (GIC[2]) on banks so-equipped[3]
    e. Monitor MVAR loss of all EHV transformers as possible

[1] Requires proper instrumentation (e.g., fiber to hot-spot). Note there may be unusual heating in a location other than the normal hot-spot location. Dissolved gas analysis may be available in real-time if the transformer is so-equipped; otherwise, post-event DGA may be performed.

[2] 10 amperes per phase GIC is a good starting point for potential impacts on heavily loaded transformers when actual limits are unknown. Newer transformers may have significantly higher GIC withstand capability if specified at the time of construction. For vulnerable transformers, the OEM can perform analytical withstand studies to better define a particular design's GIC vs. Time withstand capability

[3] Regarding the effects of GIC on transformers, real-time mitigation (after a storm is already in progress) should not be taken based solely on a single indicator (e.g., increased GIC). At least one additional indicator should be monitored to determine if the transformer is actually being adversely affected (e.g., increased MVAR loss, abnormal temperature rise, etc)

f. Prepare for unplanned capacitor bank/SVC/HVDC tripping[4]
g. Prepare for possible false SCADA/EMS indications if telecommunications systems are disrupted (e.g., over microwave paths)

2. Safe system posturing (only if supported by study)
   a. Start off-line generation, synchronous condensers
   b. Enter conservative operations with possible reduced transfer limits
   c. Ensure series capacitors are in-service (where installed)

Real-time actions (based on results of day-of-event monitoring):

1. Safe system posturing (only if supported by study)
   a. Selective load shedding[5]
   b. Manually start fans/pumps on selected transformers to increase thermal margin (check that oil temperature is above 50° C as forced oil flow at lower temperatures may cause static electrification)
2. System reconfiguration (only if supported by study)
   a. Remove transformer(s) from service if imminent damage due to overheating (possibly automatic by relaying)
   b. Remove transmission line(s) from service (especially lines most influenced by GMD)

Return to normal operation

This should occur two to four hours after the last observed geomagnetic activity.

Related Documents and Links

2012 Special Reliability Assessment Interim Report: Effects of Geomagnetic Disturbance on the Bulk Power System, dated February 2012
http://www.nerc.com/files/2012GMD.pdf

Industry Advisory: Preparing for Geomagnetic Disturbances, dated May 10, 2011
http://www.nerc.com/fileUploads/File/Events%20Analysis/A-2011-05-10-01_GMD_FINAL.pdf

[4] Consideration should be given to replacing protective relaying (as part of planned GIC mitigation projects) to prevent false tripping of reactive assets due to GIC should be considered. Note that capacitor units have harmonic overload limits that should be observed (see IEEE Std 18).
[5] Giving preference of course to the most critical/sensitive loads (e.g., national security, nuclear fuel storage site, nuclear plant offsite sources, chemical plants, emergency response centers, hospitals, etc)