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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Geomagnetic Disturbance (GMD) Background

While much research into space weather/geomagnetic storm impacts on technology systems has focused upon the dynamics of the space environment. The role of the design and operation of the technology system in introducing or enhancing vulnerabilities to space weather is often overlooked. In the case of electric power grids, both the manner in which systems are operated and the accumulated design decisions engineered into present-day networks around the world have tended to unknowingly and significantly enhance geomagnetic storm impacts. The result is to increase the vulnerability of this critical infrastructure to space weather/geomagnetic storm disturbances.

The geomagnetic disturbances can threaten bulk power system reliability. Most well-known recent experience in North America was the March 13-14, 1989 geomagnetic storm, which led to the collapse of the Hydro Québec system in the early morning hours of March 13, 1989. The threat from GMD events have gained renewed attention as recent investigations have suggested the severity of solar storms may be higher and reach lower geographic latitudes than formerly expected. For example, this High Impact, Low Frequency event risk was identified as threat to bulk power system reliability in a joint report by NERC and the US Department of Energy in April 2010[1].

Severe-impact geomagnetic disturbance (GMD) events present risks and vulnerabilities that are not fully addressed in conventional bulk power system planning, design, and operating processes. Geomagnetic storms emanating from the sun can produce an impulsive disturbance to earth's geomagnetic field over wide geographic regions. This field disturbance causes induced quasi-DC ground currents (geomagnetically induced currents or GIC), which can, depending on the ground impedances, flow through the high voltage system. These currents can saturate transformers causing them to demand high levels of reactive support, generate large amounts of harmonics and heating that can damage high voltage and generator step-up transformers.

As storm intensity increases both the geographic footprint and resulting levels of GIC flow increase which can simultaneously exposes many transformers across the network. At each exposed transformer, the level of saturation of the transformer core increases with increasing GIC levels and also increases reactive power consumption. Because GIC flows are occurring simultaneously in many transformers, this could lead to voltage regulation problems throughout the network.

The EHV portion of the grid 345 to 765 kV will typically experience the highest GIC flow levels. These lines and connected transformers also have lower resistance per mile than the lower voltage (115-230kV)

[1] The High Impact, Low Frequency Report can be found here: http://www.nerc.com/files/hilf.pdf

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underlying systems. The lower resistance for the EHV lines and transformers will cause proportionately larger GIC flows and therefore concentration of GIC to occur in the highest voltage portions of the network. More important, the higher kV-rated lines and transformers are key network elements, as they are the long-distance heavy haulers of the power grid. The upset or loss of these key assets due to large GIC flows can rapidly cascade into geographically widespread disturbances to the power grid.

Any 765 kV, 500 kV, and 345 kV single phase units whether they are either core form or shell form are highly susceptible to saturation from GIC. However, identifying the type of transformer that may be more susceptible to damage from GIC can be challenging due to specific design parameters and construction. Depending on the location and concentration of stray flux internal to the transformer, heating of the oil, hot spots on various tank or core locations and internal windings and other structures within the transformer can occur that damages the transformer insulation systems. Further, during saturation, the reactive demands increase proportional to the transformer operating voltage (i.e. a 765kV transformer will produce twice as much MVAr demand as a 345kV transformer with the same level of GIC), and it emits substantial amounts of both even and odd harmonics making traditional relaying challenging.

Many organizations have operating procedures in place to address the potential impacts of GMD. However, the extent of protection from these actions is not well understood.