Calculation of GIC in Bulk Power Systems

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Outline

- Background
- Geoelectric Field Calculations
- System Modeling and GIC Calculations
- Conclusions
Background

• During geomagnetic disturbances, magnetic field variations at the earth’s surface drive low frequency electric currents along transmission lines and through transformer windings to ground wherever there is a path for them to flow.
• Driving force is the induced EMF in the transmission lines
• GIC are considered quasi-dc because of their low frequency (10uHz – 1Hz) relative to the power frequency
Background

\[ V = \int \vec{E} \cdot d\vec{l} \]

- \( V_{\text{induced}} \)
- GIC
- Rest of System
- Geoelectric Field

\[ \int = \text{Rest of System} \]

\[ \text{Geoelectric Field} \]
Background

Example GIC

Pulse widths are generally on the order of 2-10 minutes
Geoelectric Field Calculations

Time Series Geomagnetic Field $B(t)$ → $1/\mu_0$ → FFT → Earth Surface Impedance $Z(\omega)$ → IFFT → Time Series Geoelectric Field $E(t)$

$Z(\omega)$ acts as a high pass filter
dc Transformer Model

GSU Example

Autotransformer Example
Transmission Line Model

Bus A (LAT,LON)

Bus B (LAT,LON)

\[ V = \oint \vec{E} \cdot d\vec{l} \]

If uniform E field

\[ \vec{E} \cdot \vec{L} = E_x L_x + E_y L_y \]

1 Phase Mapping

\[ R_{dc} \]

\[ R_{dc} \]

\[ R_{dc} \]

\[ R_{dc}/3 \]

Bus A (LAT,LON)

Bus B (LAT,LON)

\[ E = E_x L_x + E_y L_y \]
Substation Ground Grid and GIC Mitigation Device Models

- The substation ground grid resistance including the effects of any grounded line conductors (e.g. shield wires or neutrals) is required.
- A capacitive GIC blocking device presents very high impedance to GIC; thus, it can be modeled as a high resistance (e.g. 1.0 MΩ), whereas, the actual resistance of a resistive blocking device is used.
GIC Calculations

- Once the dc model has been assembled, the resulting GIC flows can be computed using any suitable circuits technique.
  - \( I = [G]V \)
  - For large systems (typical), sparse matrix techniques are employed
- Node voltages (\( V = [G]^{-1}I \)) are computed, then the GIC flows are computed.
Conclusions

• The process for computing GIC in a bulk power system was presented.
• The various steps for determining the geomagnetic field that is to be evaluated was provided.
• Guidance on assembling the dc system model and computing the GIC flows were also provided.