# GIC module to analyze geomagnetic disturbances on the grid

## PSS®E

### At a glance

Geomagnetic Disturbances (GMDs) occur when solar energetic particles from the sun migrate to the earth. These auroral electrojets cause short-term variations in the earth's magnetic field. The changes in earth's magnetic field create an electric field over the surface of the affected region, which in turn induces voltages in high-voltage transmission lines.

The induced voltages in transmission lines cause Geomagnetically Induced Currents (GICs) to flow if there is a closed path for currents to circulate. These closed paths in the electrical grid typically exist in the transformer grounding connections. GICs are low frequency currents (below 1 Hz). Their flow through transformers result in half-cycle saturation leading to increased VAR losses and harmonic distortion that may lead to voltage stability problems.
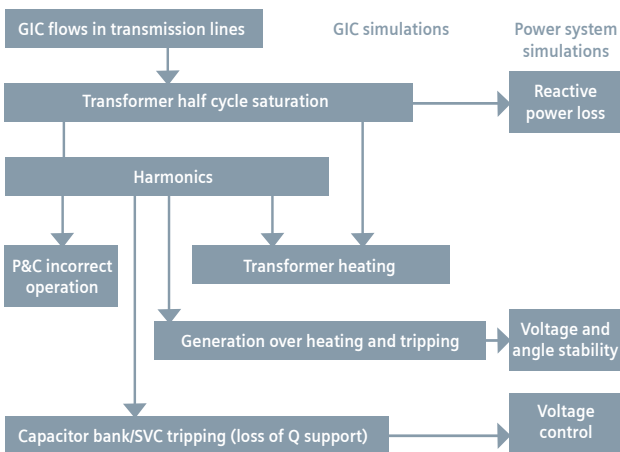
### The Challenge

Power system planners and operators require technical tools to conduct studies to assess the impact of GIC currents in the power grid and prepare mitigation measures.

### Our Solution

PSS®E Versions 32.2 and 33.3 introduced a value-added GIC module to analyze the effects on a transmission network. The base AC network is converted to resistive DC network as shown in Figure 2 to calculate GICs flowing in network.

The method used is the Induced Voltages in Transmission Lines as voltage sources. This method of calculation is recommended by NERC GMD Task Force.
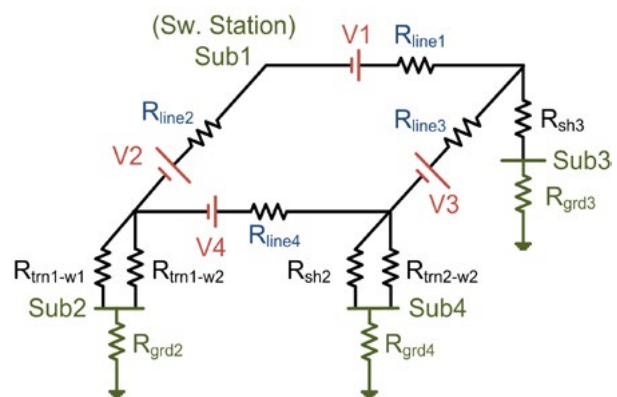


Figure 1: Potential effects of GIC on the power system grid



Figure 2: DC Network Representation in GIC calculations

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The induced voltages are calculated considering (a) Uniform geomagnetic field, (b) Benchmark GMD event (TPL-007-1), and (c) Non-uniform geomagnetic field.

The GICs flowing in the network are dependent on the earth conductivity structure. The PSS®E GIC module has a built-in data base that includes North American earth conductivity models. Additionally, custom earth conductivity models can be provided.

In addition to the basic PSS®E power flow network data, the GIC module requires additional data that can be input through the GIC module graphical user interface (GUI) within PSS®E. This will create an auxiliary text file with an extension of *.GIC[1].

The input data required in the *.GIC file for calculations are:

- Geographic location (longitude and latitude) for substations
- Grounding resistance and earth conductivity model data for substations
- DC winding and grounding resistance of transformers
- Identification of the GIC blocking device in the grounding connection
- Transformer vector group
- Branch DC resistance and GMD induced voltage if known
- DC resistance of bus shunts
- User earth conductivity models

Optional data for transformers[2]:

- Number of cores
- K Factor

*Note: PSS®E sequence data is not required.*

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**The results of the GIC analysis include:**

- Transmission line induced DC Voltages
- DC voltages at network buses and substation ground buses
- GIC flow in transmission lines, former windings and substation grounds
- Reactive power losses in transformers
- Substation ground and branch GIC flows
- Bus voltages

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These results can be viewed either in a text report, on a network map or in a network slider diagram. The power flow case containing the output of the GIC calculation can be saved as a Saved Case (.sav) or as a PSS®E change file.

For additional scenario analysis for a variety of power system network conditions and configurations, these saved files can be used in power flow, contingency and dynamics. Operational mitigation measures and equipment mitigation measures can be planned and implemented using these results.

**Features Summary**

- GMD Storm Scenarios that can be analyzed:
  - NERC TPL-007-1 Benchmark event
  - Non-uniform geoelectric field
  - Uniform geoelectic field
  - Any of above three with localized geoelectric hotspots
  - Combination of GMD storms with different strength and orientation experienced in different regions of grid
- Regional Conductivity Maps that can be modeled:
  - 1D earth conductivity models of physiographic regions of the USA (geomag.usgs.gov/conductivity) and Canada
  - Users can provide 1D earth conductivity model data for any specific earth conductivity model
- Transformer winding configurations that can be modeled:
  - Two winding transformers
  - Two winding auto transformers
  - Three winding transformers
  - Three winding auto transformers
  - Phase Angle Regulators (PARs)
- Underground cables can be modeled
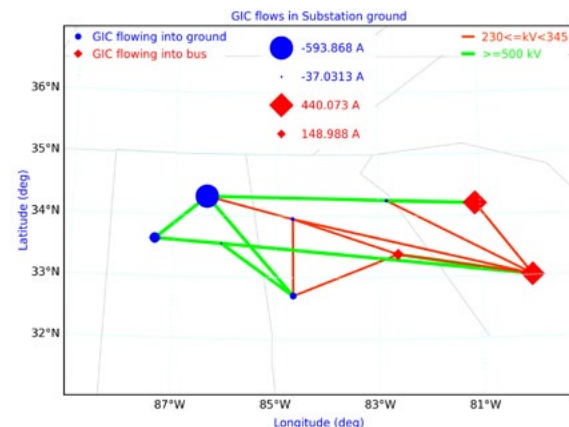- Microsoft® Excel interface to create GIC data file



Figure 3: Geospatial Plot Showing Effects of GIC on bus voltages and substations

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[1] If desired, the *.GIC file can be created using any text editor, or Microsoft® Excel.
[2] If not provided, default values will be used.

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