Attachment G: Geomagnetic Induced Current Modeling Criteria

GMD events cause very low frequency (quasi-dc) voltages in the power system network. The quasi-dc voltages drive Geomagnetically-Induced Currents (GIC) along transmission lines and through transformer windings to ground. The GIC flows through transformer windings and leads to increased transformer hotspot heating, harmonic generation, and reactive power absorption, each of which can impact system reliability. Computation of GIC flows are performed using circuit analysis techniques with a DC system model (GIC system model). As all other power flow analysis is performed with an AC system model, many of the data parameters need to be adjusted to their equivalent DC value.

GMD vulnerability assessments are applicable to facilities that include high side, wye-grounded winding power transformers with terminal voltage greater than 200 kV. To appropriately conduct GMD vulnerability assessments for the applicable facilities in the NYCA, the GIC system model needs to include the modeling data for facilities 200 kV and greater as well as underlying system facilities that have the potential to add GIC flow to the applicable facilities, such as 115 kV transmission paths in parallel with the transmission paths of applicable facilities greater than 200 kV and generation facilities connected to these paths.

Within the New York Control Area (NYCA), both Transmission Owners and Generator Owners are responsible for providing the modeling data for their facilities. Generator owners with a Generator Step-Up (GSU) transformer that are high side, wye-grounded with terminal voltage greater than 200 kV shall provide their modeling data to the NYISO. If a Transmission Owner deems that Generator Owner facilities connected to its transmission system at less than 200 kV (connected either directly or through a Generator Step Up (GSU)) is significant to the calculation of GIC, those Generator Owners shall provide the requested GIC modeling information to the NYISO. To the extent feasible and appropriate, the NYISO will notify and request data from Generator Owners with facilities connected to the transmission system at less than 200 kV that the Transmission Owners deemed significant. Data coordination between adjacent Transmission Owners, Generator Owners, and the NYISO will use the standard practices and procedures for the development of power flow and short circuit data. The NYISO will coordinate data on inter-area tie lines with adjacent Planning Coordinators.

Most of the data requirements in this Attachment are adopted from NERC GMD Task Force documentation, Siemens PTI PSS®E Program Operation Manual, and the NPCC Geomagnetically Induced Current (GIC) Modeling Data Collection White Paper (RCC Approved June 1, 2016).

The NYISO develops the GIC system model from a combination of information from AC power flow models, available equipment resistance data, and geographic information for the substations. Attachment A provides a standard template for data reporting. The sections below describe the data that the NYISO needs for developing the GIC system model. Submitted modeling data must comply with the format specified in the GIC data template. All correspondence related to GIC modeling requirements must be sent to the NYISO via email at system_analysis_data@nyiso.com.

Substation Data

Table 1 provides a summary of the required substation data that corresponds to the “SubstationData” tab of Attachment A.

Table 1. Summary of Substation Data

Data Field	Description
Substation	Allowed values a 1 though 999997. No default values are allowed. It is recommended that each facility owner start their templates using the value “1”. The NYISO, in compiling the modeling data, will renumber substations in the order to which they are compiled in the system-wide model.
List of Buses	List of six digit bus numbers that correspond to the substation number. Facility owners without access to the PSS®E power flow model can contact the NYISO for assistance in determining the appropriate six digit bus number. The bus number must be present in the power flow network data. No default values are allowed. The following restrictions apply when assigning bus and substation: • Two buses connected by a transmission line (non-transformer branch) must be in different substations (Note exception: when two buses representing a non-transformer branch in power flow data are indeed in the same substation, specify first character of that branch circuit identifier as greater than sign “>”). • Two buses connected by a two-winding transformer must be in the same substation. • Three buses connected by a three-winding transformer must be in the same substation. Two buses connected by zero impedance line must have the same substation number.
Name	Alphanumeric identifier assigned to substation. The name may be up to 12 characters and may contain a combination of blanks, upper case letters, numbers, and special characters (the first character may not be a minus sign). If the substation name contains blanks or special characters the name must be enclosed in single or double quotes. The name field is 12 blanks by default. For the development of the NYCA-wide model, substation names must be provided.
Latitude	Substation geographic latitude, positive for north and negative for south. No default values are allowed. Coordinate is to be provided in decimal degrees with at least 6 decimal places. Note that North and East are defined as positive; South and West are defined as Negative.
Longitude	Substation geographic longitude, positive for east and negative for west. No default values are allowed. Coordinate is to be provided in decimal degrees with at least 6 decimal places.
Rg (ohm)	Substation DC grounding resistance in ohms. If RG<= 0.0 or RG>=99.0 the software assumes that the substation is ungrounded. The default substation grounding resistance is 0.1 ohm. The substation grounding resistance is the resistance to remote earth from the substation ground grid. The fundamental AC resistance is typically used as the substation grounding resistance because it is approximately equivalent to the DC resistance. Only a single substation grounding resistance is allowed for each substation; thus, it is connected to a common “neutral” bus in the network model.[1]

[1] NERC GID Application Guide, Computing Geomagnetically-Induced Current in the Bulk-Power System, dated December 2013.

<table>
<tr><th>Data Field</th><th>Description</th></tr>
<tr><td>Earth Model</td><td>Earth model, associated with a station. The NYISO recommends using the earth models developed by the United States Geological Survey (USGS).[2]

The list below identifies the applicable conductivity regions for the New York Control Area.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>AK1A</td><td>Adirondack Mountains-1A</td></tr>
<tr><td>AP2</td><td>Northern Appalachian Plateaus</td></tr>
<tr><td>CP1</td><td>Coastal Plain</td></tr>
<tr><td>NE1</td><td>New England</td></tr>
<tr><td>PT1</td><td>Piedmont</td></tr>
<tr><td>SL1</td><td>St. Lawrence Lowlands</td></tr>
</table>
</td></tr>
<tr><td>RG Flag</td><td>This is used for information only. Possible methods include “Assumed,” “Measured,” “Calculated,” or any similar brief comment. The RG Flag value may be up to 40 characters in length. The default RG Flag is “Assumed.”</td></tr>
</table>

Transformer Data

Table 2 provides a summary of the required substation data that corresponds to the “TransformerData” tab of Attachment A.

Power transformers are represented by their DC equivalent circuits. Resistance values used for modeling transformers are best obtained from their transformer test reports. If the transformer test reports are not available, Table 3 provides a method for calculating the best estimate of the data.[1]

Transformer test reports may not explicitly state the DC winding resistances needed for GIC system models. Figure 1 provides an example of data from a transformer test report.

RESISTANCE IN OHMS AT 85°C		
WINDINGS		
H	X	Y
.0779	.2985	.0152

Figure 1 Example Transformer Test Report[3]

The DC winding resistance can be determined using the values shown in Figure 1 as follows:

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[2] http://geomag.usgs.gov/conductivity/

[3] Geomagnetically Induced Current (GIC) Modeling Data Collection White Paper, Prepared by SS-37 Working Group on Base Case Development, RCC Approved June 1, 2016.

- H typically represents the sum of the three-phase resistances between H and X.
- X typically represents the sum of the three-phase resistances between X and H0X0.

Therefore, to determine the transformer winding DC resistance in ohms/phase, the primary winding resistance is typically H/3 ohms and the secondary winding DC resistance is typically X/3 ohms.

Generator Step-Up Transformers[1]

The DC equivalent circuit of a GSU is provided in Figure 2. The delta winding is not included in the GIC equivalent circuit because it does not provide a steady state path for GIC flow. The H0 terminal refers to the neutral point that is ordinarily connected directly to the substation ground grid model.

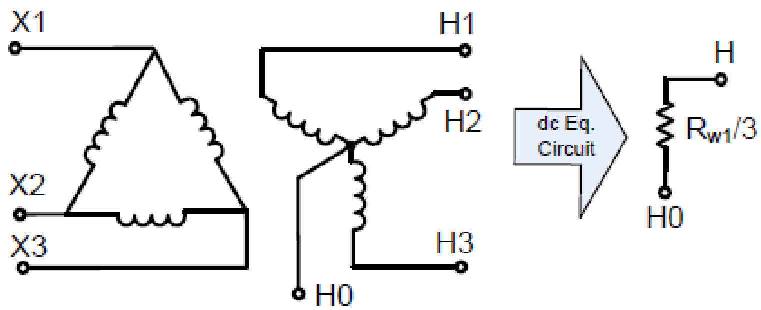

Figure 2 Single-Phase DC Equivalent Circuit of a GSU[1]

For situations where the DC resistance of the grounded-wye winding is not available using the most appropriate or best estimate methods stated in Table 3, an approximation may be made using the positive sequence resistance data. The per-unit positive sequence resistance R_{HX}, includes both the resistance of the high-voltage winding (ohms), R_H, and the referred value of the low-voltage winding (ohms), R_X. Equation (1) shows how to calculate R_{HX} where Z_{bh} refers to the base impedance (ohms) on the high-voltage side of the transformer and n is the transformer turns ratio.

$$R_{HX} = \frac{R_H + n^2 R_X}{Z_{bh}} \tag{1}$$

An assumption made in Equation (1) is that the high-voltage winding resistance and the referred value of the low-voltage winding are approximately equal; thus, the resistance of the high-voltage winding can be estimated using Equation (2). The skin effect and changes in resistance as a function of winding operating temperature are usually ignored.

$$R_H = \frac{1}{2} R_{HX} Z_{bh} \tag{2}$$

Two and Three Winding Transformers[1]

The DC equivalent circuit of both a two-winding and three-winding transformer is provided in Figure 3. The delta tertiary winding (if applicable) is not included in the GIC model because it does not provide a steady state path for GIC flow. Both winding neutral nodes (X0 and H0) are explicitly modeled. Ungrounded wye windings are excluded in GIC calculations because they do not provide a path for GIC flow.

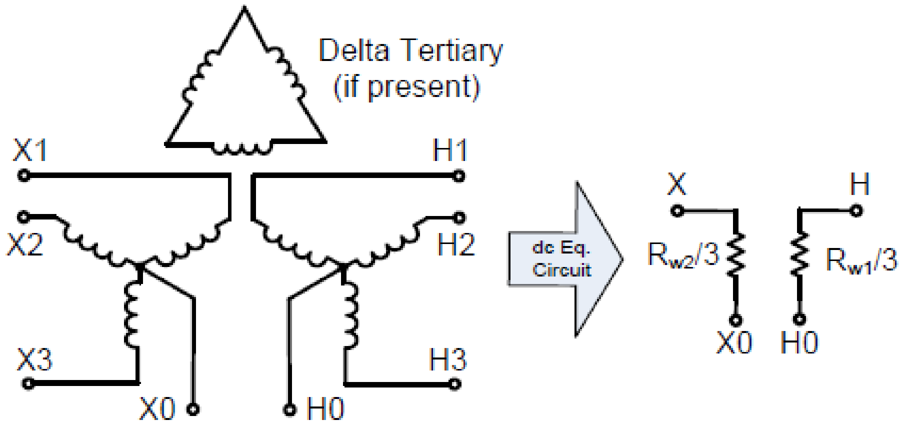

Figure 3 Single-Phase DC Equivalent Circuit of a Two-Winding or Three-Winding Transformer

Autotransformers[1]

The DC equivalent circuit of an autotransformer is provided in Figure 4. The delta tertiary winding (if applicable) is not included in the GIC model because it does not provide a steady state path for GIC flow. The common autotransformer neutral terminal (H0/X0) is modeled explicitly, and is ordinarily connected directly to the substation ground grid model. The R_s and R_C parameters are defined as the DC resistance of the series and common windings, respectively. For situations where the DC resistance is not available using the most appropriate or best estimate methods stated in Table 3, an approximation may be made using the positive sequence resistance data. Equations 3 and 4 show how to calculate R_s and R_C, respectively.

$$R_S = \frac{1}{2} R_{HX} Z_{bh} \tag{3}$$

$$R_C = \frac{1}{2} \frac{R_{HX} Z_{bh}}{(n-1)^2} \tag{4}$$

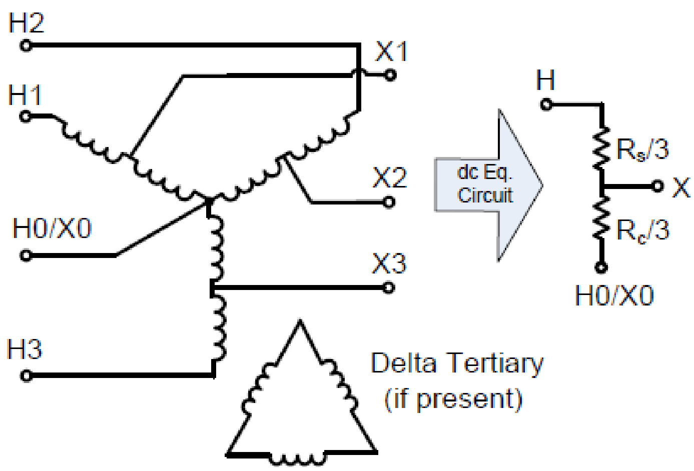

Figure 4 Single-Phase DC Equivalent Circuit of a Two-Winding or Three-Winding Autotransformer

Table 2. Summary of Transformer Data

Data Field	Description
BUSI	The bus number to which winding 1 is connected. The GIC model winding 1 connection must be the same winding 1 bus for the power flow data. No default allowed.
BUSJ	The bus number to which winding 2 is connected. The GIC model winding 2 connection must be the same winding 2 bus for the power flow data. No default allowed.
BUSK	The bus number to which winding 3 is connected. The GIC model winding 3 connection must be the same winding 3 bus for the power flow data. BUSK is assigned to 0 for two-winding transformers. No default allowed.
CKT	Alphanumeric circuit identifier. The GIC circuit alphanumeric identifier must be the same as the power flow data. No default allowed.
WRI	DC resistance of winding 1 in ohms/phase. When a value is not specified the load flow data resistance value is used (note that the load flow data value can cause a significant percentage of error to be introduced into the model). The NYISO recommends using the methods described in Table 3 to determine the appropriate model value.
WRJ	DC resistance of winding 2 in ohms/phase. When a value is not specified the load flow data resistance value is used (note that the load flow data value can cause a significant percentage of error to be introduced into the model). The NYISO recommends using the methods described in Table 3 to determine the appropriate model value.
WRK	DC resistance of winding 3 in ohms/phase. WRK is assigned to 0 for two-winding transformers. When a value is not specified the load flow data resistance value is used (note that the load flow data value can cause a significant percentage of error to be introduced into the model). The NYISO recommends using the methods described in Table 3 to determine the appropriate model value.
GICBDI	GIC blocking device in neutral of winding 1. • = 0, no GIC blocking device present • = 1, GIC blocking device present For autotransformers, if either GICBDI or GICBDJ is assigned a value of 1, that autotransformer is treated as it has a GIC blocking device present.
GICBDJ	GIC blocking device in neutral of winding 1. • = 0, no GIC blocking device present • = 1, GIC blocking device present For autotransformers, if either GICBDI or GICBDJ is assigned a value of 1, that autotransformer is treated as it has a GIC blocking device present.
GICBDK	GIC blocking device in neutral of winding 1. • = 0, no GIC blocking device present or the device is a two-winding transformer

Data Field	Description
	• = 1, GIC blocking device present
VECGRP	Alphanumeric identifier specifying vector group based on transformer winding connections and phase angles. If the vector group is specified in the power flow data that data will be used and is not needed to be specified here. For GIC calculations winding grounding connection information is used; its clock angles are not used. • The vector group must be specified considering the winding order I, J, K defined in the model. • For autotransformers, the bus with the lower base voltage is treated as the common winding bus. • For three-winding autotransformers, windings on bus 1 and bus J form the autotransformer. (For vector groupings see Siemens PTI Program Operation Manual Sections 5.5.5 and 5.5.6).
CORE	Number of cores in the transformer core design. This information is used to calculate the transformer reactive power loss from GIC flowing in its winding • =-1 for three-phase shell form • = 0 for unknown core design (default) • = 1 for single core design • = 3 for three-phase three-legged core form • = 5 for three-phase five-legged core form
KFACTOR	A factor to calculate transformer reactive power loss from GIC flowing in its winding (MVAR/AMP). KFACTOR = 0 by default. (See Table 4).
GRDWRI (ohm)	Winding 1 grounding DC resistance. Default value of 0.
GRDWRJ (ohm)	Winding 2 grounding DC resistance. Default value of 0.
GRDWRK (ohm)	Winding 3 grounding DC resistance. Default value of 0.
TMODEL	Transformer model in GIC DC network. • = 0 two/tree/auto transformer model as defined by its vector group • = 1 transformer as T model in DC network TMODEL = 0 by default

Table 3. Transformer Data Best Alternative Estimates

Network Component	Most Appropriate	Best Estimate
Grounded wye-winding of conventional transformer	Measured DC resistance of the winding at nominal tap and adjusted to 75°C.	50% of the total per-unit copper loss resistance converted to actual ohms at winding base values.
Autotransformer series windings	Measured DC resistance of each winding at nominal tap and adjusted to 75°C.	50% of the total per-unit copper loss resistance converted to actual ohms at winding base values.
Autotransformer common winding	Measured DC resistance of each winding at nominal tap and adjusted to 75°C.	50% of the total per-unit copper loss resistance converted to actual ohms at V_H winding base values and divided by $(V_H/V_x-1)^2$.

Note: Winding resistance data provided in test reports may represent the total resistance of the three phases combined. If so, the data must be converted to represent the per phase resistance.

Table 4. KFACTOR for Different core Designs[4,5]

Core Design	KFACTOR
Single Phase (Three Separate Cores)	1.18
Three-Phase Shell Form	0.33
Three-Phase, 3-Legged, Core Form	0.29
Three-Phase, 5-Legged, Core Form	0.66
Unknown core, highest winding voltage <= 200 kV	0.6
Unknown core, highest winding voltage >200 kV and <= 400 kV	0.6
Unknown core, highest winding voltage > 400 kV	1.1

Shunt Data

At low frequency shunt capacitors present a very high impedance; therefore, shunt capacitors are excluded in the GIC system representation. Shunt reactors provide a low impedance path to the flow of GIC; therefore, shunt reactors are included in the GIC system representation. Table 5 provides a summary of the required substation data that corresponds to the "FixedShuntData" or "Switched Shunt Data" tabs of Attachment A. Only "in-service" shunts are included in the GIC system representation.

Shunt data is represented by its DC equivalent value. Table 6 provides a summary of the shunt reactor best alternative estimates[1]. The DC model of a grounded-wye shunt reactor is the same as that of a grounded-wye winding of a GSU.

Table 5. Summary of Shunt Data

Data Field	Description
BUS	Bus number of the bus to which fixed shunt is connected. It must be present in power flow network data. No default allowed.
ID	Two digit alphanumeric identifier (same as the identifier in the power flow model).
R (ohm/ph)	DC resistance in ohms/phase. Value must be > 0. No default allowed. Fixed bus shunt records with R = 0 will be ignored. The NYISO recommends using the methods described in Table 6 to determine the appropriate model value.
RG (ohm)	Grounding DC resistance in ohms. Default value = 0 (no grounding resistance, solidly grounded).

Note: Attachment A Switched Shunt does not use the data field "ID".

Table 6. Shunt Reactor Data Best Alternative Estimates

Network Component	Most Appropriate	Best Estimate
Shunt reactor	Measured DC resistance of winding adjusted to 75°C.	Measured AC copper loss resistance of winding at factory test temperature.

Note: Winding resistance data provided in test reports may represent the total resistance of the three phases combined. If so, the data must be converted to represent the per phase resistance.

[4] X.Dong, Y. Liu, J.G. Kappenman, "Comparative Analysis of Exciting Current Harmonics and Reactive Power Consumption from GIC Saturated Transformers", Proceedings IEEE, 2001, pages 318-322.
[5] Siemens PTI PSSE GIC Introduction PSSC 800.

Branch Data

Table 7 provides a summary of the required branch data that corresponds to the "BranchData" tab of Attachment A. The resistive data from AC power flow and fault studies is usable for modeling line resistance in the GIC system representation; however, the best estimate[1] for unknown data is shown in Table 8. The difference between R_{DC} and R_{AC} at 50°C is less than 5% for conductors up to 1.25 inches in diameter, and less than 10% up to 1.5 inches in diameter conductor. Conductor Sizes beyond 1.5 inches in diameter should be evaluated for possible impact to model accuracy as the difference between AC and DC resistance could be significant for long transmission lines.

Although there is minimal difference between the R_{DC} and R_{AC} at the same temperature, there is considerable difference between resistance at ambient temperature and the values typically used in power flow studies. The resistance of a transmission conductor will be 10 to 15 percent higher at 50°C than at 20°C. Although less conservative, modeling branch resistance at 50°C is preferred because a loaded system is more susceptible to adverse impact under GIC conditions and the most stressful condition to study.

Shield wires are not included explicitly as a GIC source in the transmission line model. Shield wire conductive paths that connect to the station ground grid are accounted for in ground grid to remove earth resistance measurements that become part of that branch resistance in the network model.

Table 7. Summary of Branch Data

Data Field	Description
BUSI	The "from bus" number to which the branch is connected. No default allowed.
BUSJ	The "to bus" number to which the branch is connected. No default allowed.
CKT	Alphanumeric branch circuit identifier. The GIC circuit alphanumeric identifier must be the same as the power flow data. No default allowed.
RBRN (ohm/ph)	Branch DC resistance in ohms/phase. When RBRN is not specified, the power flow branch resistance is used. The NYISO recommends using the methods described in Table 8 to determine the appropriate model value.
INDVP (V)	Real part of the total branch GMD induced electric field in volts. (See note below).
INDVQ (V)	Imaginary part of the total branch GMD induced electric field in volts (See note below).
RLNSHI (ohm/ph)	DC resistance on ohms/phase of the line shunt at the bus I end of the branch. It must be > or equal to 0. If RLNSHI = 0 or is not specified (default value assumes 0) assumes that there is no ground path for this line shunt.
RLNSHJ (ohm/ph)	DC resistance on ohms/phase of the line shunt at the bus J end of the branch. It must be > or equal to 0. If RLNSHI = 0 or is not specified (default value assumes 0) assumes that there is no ground path for this line shunt.

Note: Total branch GMD induced electric field, INDUCEDV = INDVP + jINDVQ volts. Branch INDUCEDV is determined as below. For uniform field modeling IDUCEDV will be a real value, but for non-uniform field modeling the value INDUCEDV will be complex. The INDUCEDV voltage will have positive polarity at branch J (to bus).

- When INDUCEDV is not specified, GIC activity calculates this according to its options specified (NYISO recommend for Facility Owner input to model).
- When INDUCEDV is specified, it is used as GMD induced on that branch.
- When INDUCEDV is specified as INDVP = 0 and IDVQ = 0, then that branch is treated as part of the GIC DC network but does not have GMD induced voltage, like "underground cable"
- Pipe-type and solid dielectric underground cables shall be explicitly identified

Table 8. Branch Data Best Alternative Estimates

Network Component	Most Appropriate	Best Estimate
Transmission line	The DC resistance adjusted to 50°C.	The AC resistance adjusted to 50°C or 75°C.
Series line capacitor	100 μ℧ for bypassed state modeled as resistor; 1 MΩ for inserted state modeled as a resistor.	Not Applicable.

Earth Model Data

The "EarthModelData" tab of attachment is for facility owners to develop their own earth models.

The NYISO recommends using the earth models developed by the USGS.

Two-Terminal DC Data

The rectifier and converter stations are connected to the AC transmission network through converter transformers. The status (blocked or in-service) of two-terminal DC lines in the power system network representation is not considered for the GIC model. The purpose of including the two-terminal DC data is to capture the impact of the grounded windings of the converter stations where the converter transformers are not explicitly modeled in the power system network representation.

Table 9 provides a summary of the required two-terminal DC data that corresponds to the "2TDC" tab of Attachment A. Up to 10 GIC DC network elements are allowed per DC line.

Table 9. Summary of Two-Terminal DC Data

Data Field	Description
NAME	The non-blank alphanumeric identifier assigned to this DC line in the power system network representation. NAME may be up to 12 characters. No default allowed.
I	Bus number of the rectifier (IPR) or inverter (IPI) AC bus. It must be present in the power flow network data. No default allowed.
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at rectifier or inverter AC bus. This ID is used to specify which ground path. This is specific to GIC data and does not exist in power flow data. No default allowed.
R (ohm/ph)	DC resistance in ohms/phase of the grounded winding of the converter transformers. R must be ≥ 0. R = 0 or unspecified means that there is no ground path. No default allowed.
RG (ohm)	Grounding DC resistance in ohms. RG = 0 by default (no grounding resistance, solidly grounded).

VSC DC Data

Voltage Source Converter (VSC) stations are connected to the AC network through converter transformers. The status (in-service or out-of-service) of VSC stations in the power system network representation is not considered for the GIC model. The purpose of including the VSC DC data is to capture the impact of the grounded windings of the converter transformers where the transformers are not explicitly modeled in the power system network representation.

Table 10 provides a summary of the required VSC DC data that corresponds to the "VSCDC" tab of Attachment A. Up to 10 GIC DC network elements are allowed per VSC DC line.

Table 10. Summary of VSC DC Data

Data Field	Description
NAME	The non-blank alphanumeric identifier assigned to this VSC DC line in the power system network representation. NAME may be up to 12 characters. No default allowed.
I	Converter AC bus number (IBUS). It must be present in the power flow network data. No default allowed.
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at AC bus. This ID is used to specify which ground path. This is specific to GIC data and does not exist in power flow data. No default allowed.
R (ohm/ph)	DC resistance in ohms/phase of the grounded winding of the converter transformers. R must be ≥ 0. R = 0 or unspecified means that there is no ground path. No default allowed.
RG (ohm)	Grounding DC resistance in ohms. RG = 0 by default (no grounding resistance, solidly grounded).

Multi-Terminal DC Data

Multi-Terminal converters are connected to the AC network through converter transformers. The status (blocked or in-service) of the multi-terminal DC lines in the power system network representation is not considered for the GIC model. The purpose of including the multi-terminal DC data is to capture the impact of the grounded windings of the converter transformers where the transformers are not explicitly modeled in the power system network representation.

Table 11 provides a summary of the required multi-terminal DC data that corresponds to the "MTDC" tab of Attachment A. Up to 10 GIC DC network elements are allowed per DC line.

Table 11. Summary of Multi-Terminal DC Data

Data Field	Description
NAME	The non-blank alphanumeric identifier assigned to this multi-terminal DC line in the power system network representation. NAME may be up to 12 characters. No default allowed.
I	Converter AC bus number (IB). It must be present in the power flow network data. No default allowed.
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at AC bus. This ID is used to specify which ground path. This is specific to GIC data and does not exist in power flow data. No default allowed.
R (ohm/ph)	DC resistance in ohms/phase of the grounded winding of the converter transformers. R must be ≥ 0. R = 0 or unspecified means that there is no ground path. No default allowed.

Data Field	Description
RG (ohm)	Grounding DC resistance in ohms. RG = 0 by default (no grounding resistance, solidly grounded).

FACTS Device Data

The FACTS device converters are connected to the AC network through converter transformers. The status (in-service or out-of-service) of FACTS devices in the power system network representation is not considered for the GIC model. The purpose of including FACTS device data is to capture the impact of the grounded windings of the FACTS devices that are not explicitly modeled in the power system network representation.

Table 12 provides a summary of the required FACTS device data that corresponds to the "FACTS" tab of Attachment A.

Table 12. Summary of FACTS Device Data

Data Field	Description
NAME	The non-blank alphanumeric identifier assigned to this FACTS device in the power system network representation. NAME may be up to 12 characters. No default allowed.
I	FACTS device sending end bus number (IBUS). It must be present in the power flow network data. No default allowed.
ID	One- or two-character non-blank alphanumeric identifier. There could be more than one ground path at AC bus. This ID is used to specify which ground path. This is specific to GIC data and does not exist in power flow data. No default allowed.
R (ohm/ph)	DC resistance in ohms/phase of the grounded winding of the converter transformers. R must be ≥ 0. R = 0 or unspecified means that there is no ground path. No default allowed.
RG (ohm)	Grounding DC resistance in ohms. RG = 0 by default (no grounding resistance, solidly grounded).

Load Data

Only in-service loads provided on this data record are modeled in the GIC DC network. Table 13 provides a summary of the required load data that corresponds to the "Load" tab of Attachment A.

Table 13. Summary of Load Data

Data Field	Description
I	Bus number of the bus to which the load is connected. It must be present in the power system network representation. No default allowed.
ID	One- or two-character non-blank alphanumeric identifier.
R (ohm/ph)	DC resistance in ohms/phase of grounded load. R must be ≥ 0. R = 0 or unspecified means that there is no ground path And will be ignored.
RG (ohm)	Grounding DC resistance in ohms. RG = 0 by default (no grounding resistance, solidly grounded).