Grounding Resistance

- Substation grounding resistance is the resistance in ohms between the substation neutral and earth ground (zero-potential reference)
- An actual "fall of potential" test is the best way to determine this resistance
- Simulator provides defaults based on number of buses and highest nominal kV, but research has shown this to be a poor substitute for actual measurements
  - Simulator defaults range from 0.1 to 2.0 Ω
  - Substations with more buses and higher nominal kV are assumed to have lower grounding resistance
- Grounding resistance is not necessary for substations that have no transformer or switched shunt connections to ground

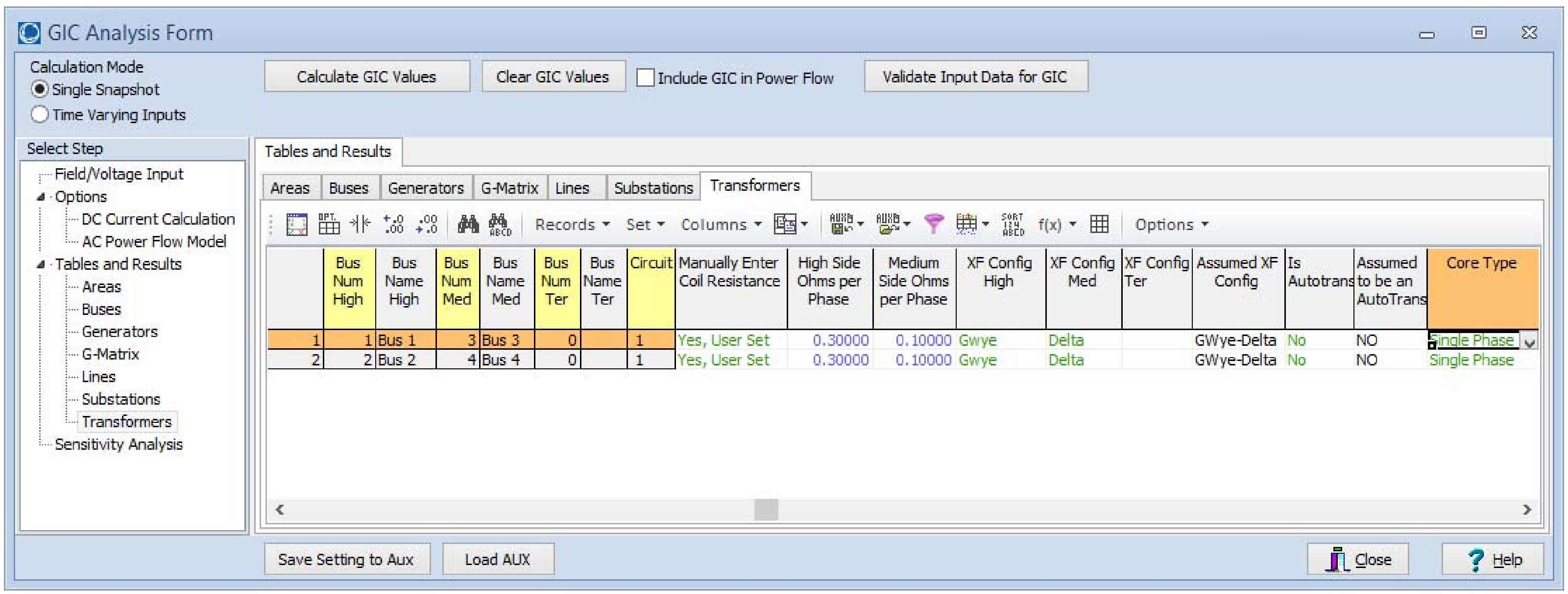
Substation Coordinates

- Longitude and latitude should be provided for all substations that contain terminals of lines for which a GIC equivalent DC voltage is applied
  - Generally this includes all lines greater than minimum length and nominal kV specified on GIC Analysis Form
  - Series compensated line terminals may be disregarded, if there are no other lines that meet above criteria
- The need for coordinates applies regardless of whether the substation contains grounded transformers
- If there are no grounded transformers, the location may be approximate (e.g. within 100 km)

Transformer Inputs

- Key inputs
  - Coil resistance (DC ohms)
  - Grounding configuration
  - Autotransformer? (Yes/No)
  - Core Type

Most essential parameters; these determine the basic topology of the GIC network



Transformer Inputs

- Manually Enter Coil Resistance
  - "Yes": user enters "High Side Ohms per Phase" and "Medium Side Ohms per Phase"
  - "No": Simulator estimates values
- XF Config High and XF Config Med: most common options are "Gwye" and "Delta"
  - Tertiary windings are assumed Delta
- Is Autotransformer: "Yes", "No", or "Unknown"
- Core Type

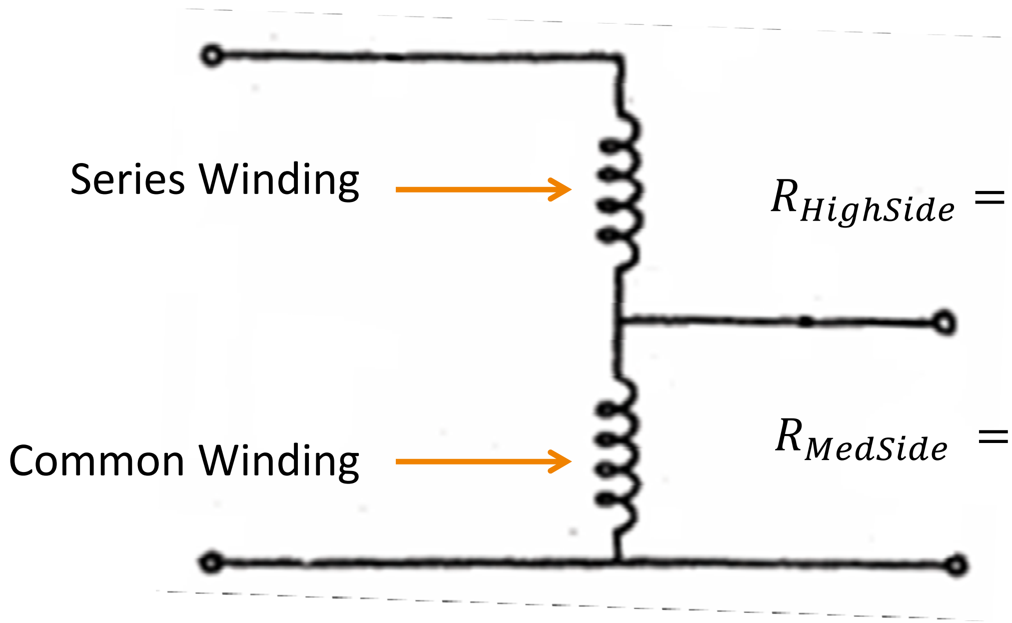
Simulator Assumptions

- It is always best to provide known quantities, especially for configuration and autotransformer fields
- If any transformer information is unknown, Simulator uses default values
- Coil Resistance
  - ohms per phase estimate based on positive-sequence AC per-unit series resistance and transformer impedance base
  - Assumed split between each winding:

$$R_{pu} * R_{Base,HighSide} = R_{HighSide} + a_t^2 R_{MedSide}$$

$$R_{HighSide} = a_t^2 R_{MedSide}$$

Coil Resistance: Autotransformers



Simulator Fields

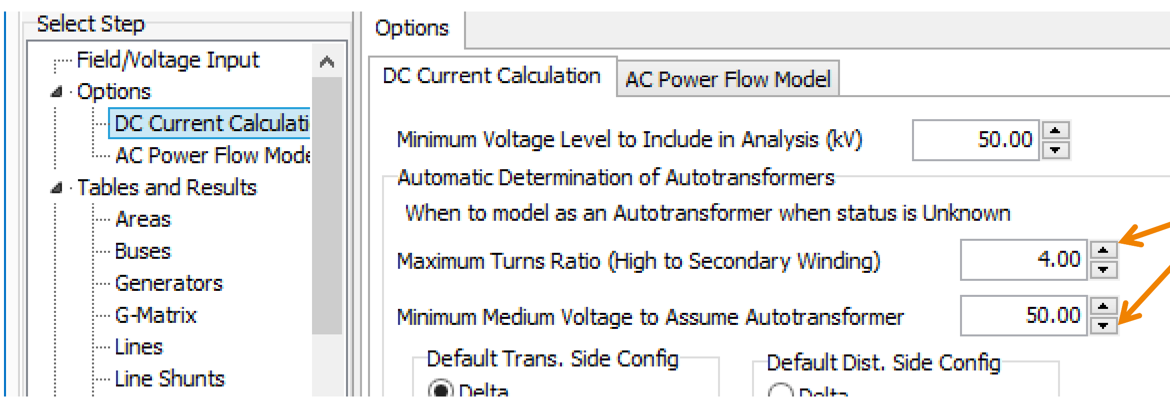
$R_{HighSide}$ = Coil Resistance (Ohms) for High Winding

$R_{MedSide}$ = Coil Resistance (Ohms) for Medium Winding

- Tertiary Windings are assumed delta connected and coil resistance is not normally populated

Simulator Assumptions: Autotransformers

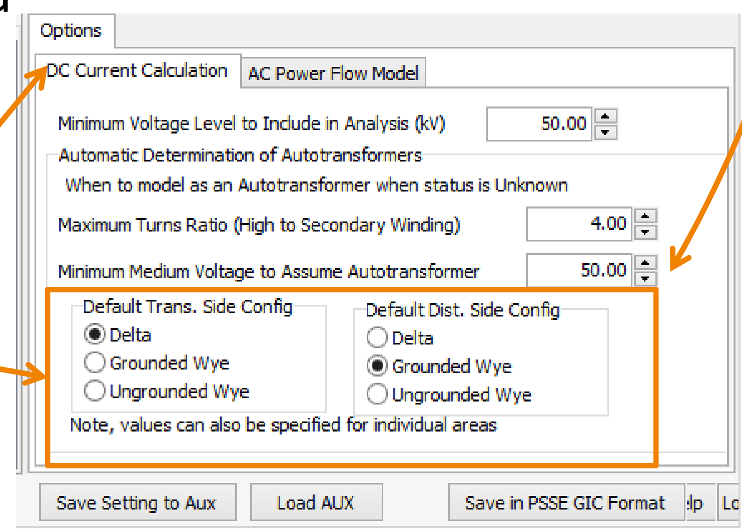
- Some parameters for assumptions applied to unknown transformers are at **Options → DC Current Calculation**
- Units are assumed to be autotransformers if all of the following criteria are met
  - unit is not a phase-shifting transformer
  - high side and low side are at different nominal voltages
  - high side nominal voltage is at least 50 kV
  - turns ratio is less than or equal to 4



These parameters may be adjusted at **Options → DC Current Calculation**

Simulator Assumptions: Transformer Configuration

- "Unknown" windings are assumed either Delta, Grounded Wye, or Ungrounded Wye
- Autotransformer Minimum High Side Winding Voltage (kV) is also the assumed delineation between transmission and distribution voltages (default 50 kV, referred to as kV_{min} hereafter on this slide)
- If high side > kV_{min} and low side is connected to a radial generator OR if high side >= 300 kV and low side < kV_{min}, unit is assumed a GSU with high side Gwye and low side Delta
- If both sides > kV_{min} OR both sides < kV_{min}, both are assumed Gwye
- Otherwise, if high side > kV_{min} and low side < kV_{min} or has radial load, use *Default Trans. Side Config* and *Default Dist. Side Config* on **Options → DC Current Calculation** (or as specified by area)



Simulator Assumptions

- I_{Eff} is per-phase "effective GIC", computed from GIC in high and low side windings and turns ratio (a_t)

$$I_{Eff,pu} = \left| \frac{a_t I_H + I_L}{a_t I_{base}} \right|$$

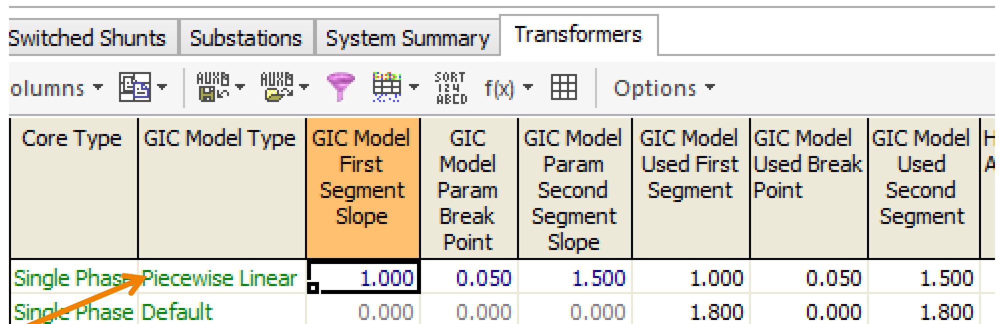
- *K-Factor* relates transformer's effective GIC (I_{GIC}) to 3-phase reactive power loss at nominal voltage

$$Q_{loss,\mathrm{pu}} = V_{pu} K_{pu} I_{Eff,\mathrm{pu}}$$

- This looks like a constant current MVar load at the transformer's high-side bus

K-Factor

- *K-Factor* may be entered directly as a 2-step piecewise linear value with "GIC Model Type" set to **Piecewise Linear**



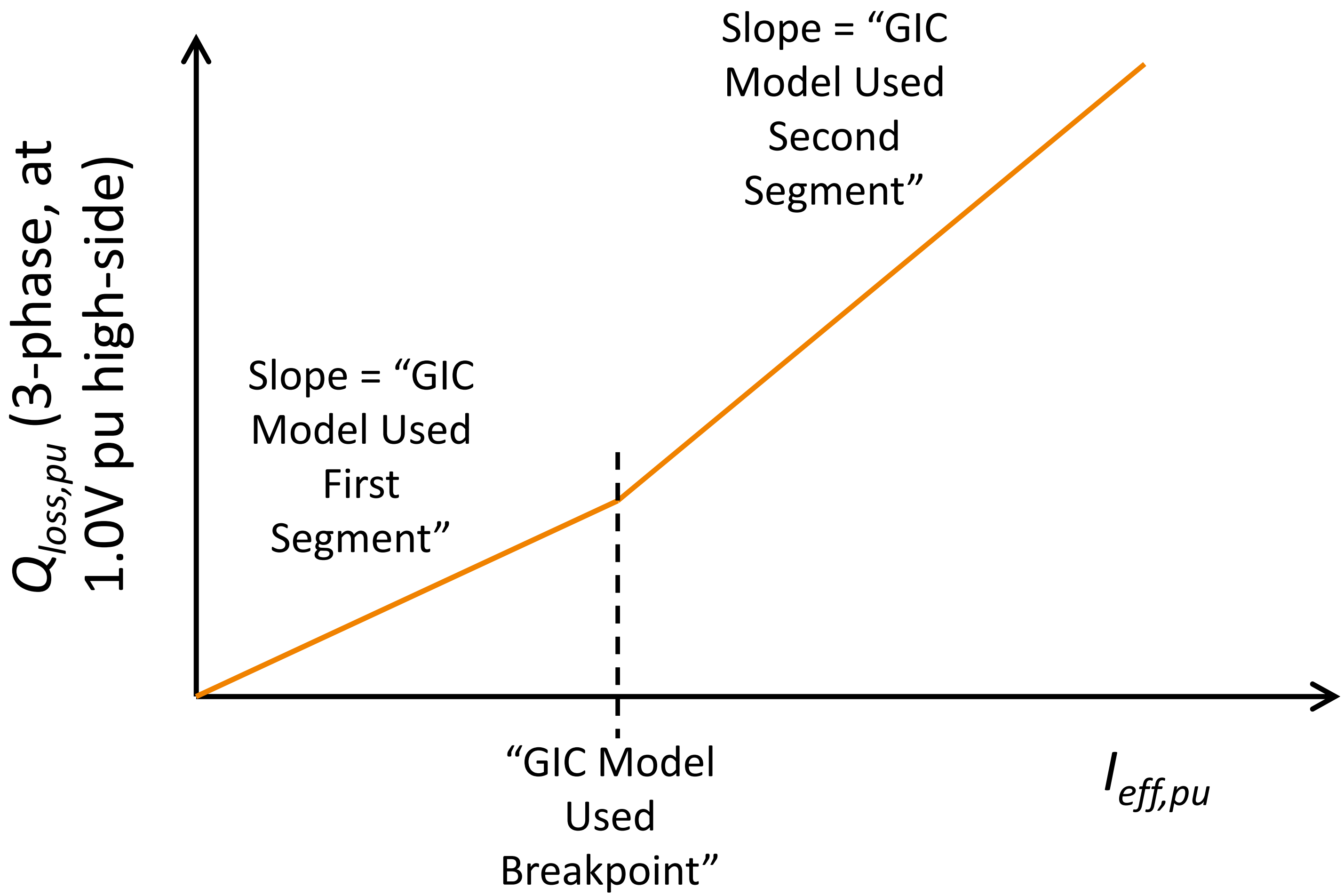
Core Type	GIC Model Type	GIC Model First Segment Slope	GIC Model Param Break Point	GIC Model Param Second Segment Slope	GIC Model Used First Segment	GIC Model Used Break Point	GIC Model Used Second Segment	H A
Single Phas	Piecewise Linear	1.000	0.050	1.500	1.000	0.050	1.500	
Single Phase	Default	0.000	0.000	0.000	1.800	0.000	1.800	

User-specified values

Values Used

- Break point is $I_{eff,pu}$
- With "GIC Model Type" set to **Default**, K-Factor is based on Core Type and parameters at **Options → AC Power Flow Model**

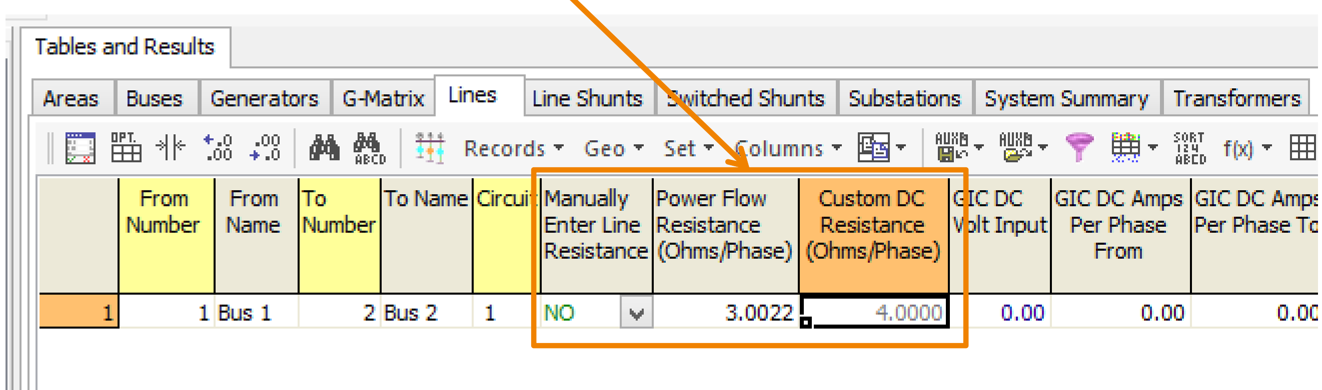
K-Factor



Slope = "GIC Model Used Second Segment"
Slope = "GIC Model Used First Segment"
$Q_{loss,pu}$ (3-phase, at 1.0V pu high-side)
"GIC Model Used Breakpoint"
$I_{eff,pu}$

Transmission Line Inputs

- DC resistance is derived from AC per-unit resistance and the impedance base by default (assumes skin effect is negligible at 60 Hz)
- You may also specify DC resistance
  - **Manually Enter Line Resistance** = YES
  - Provide value in **Custom DC Resistance (Ohms/Phase)**



	From Number	From Name	To Number	To Name	Circuit	Manually Enter Line Resistance	Power Flow Resistance (Ohms/Phase)	Custom DC Resistance (Ohms/Phase)	GIC DC Volt Input	GIC DC Amps Per Phase From	GIC DC Amps Per Phase To
1	1	Bus 1	2	Bus 2	1	NO	3.0022	4.0000	0.00	0.00	0.0C

Switched Shunt Inputs

- Shunts operating as inductors can also provide a conducting path for GIC
- Simulator assumes shunts have infinite resistance by default, but resistances may be provided by the user
- Inductors are assumed to have non-magnetic core designs and thus not subject to saturation and MVar losses as in transformers (i.e. K=0)
- Shunts operating as capacitors always have infinite resistance