Introduction to PowerWorld Simulator: Interface and Common Tools

I11: Linear Sensitivity Analysis

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Linear Analysis

- Power Transfer Distribution Factors (PTDFs)
- Shift Factors
- Multiple Direction PTDFs
- Multi-Element Shift Factors
- Line Outage Distribution Factors (LODFs)
- Outage Transfer Distribution Factors (OTDFs)
- Flow and Voltage Sensitivities
  - Line Flows, Interface Flows, Bus Voltages, Losses
- Loss Sensitivities
- Line Loading Replicator
- Connections Menu

Power Transfer Distribution Factors (PTDFs)

- PTDF is a term defined by NERC to indicate the incremental impact a transfer of power between areas has on system flows.
- PTDFs can be calculated in Simulator by selecting **Tools** ribbon tab → **Sensitivities** → **Power Transfer Distribution Factors (PTDFs)**.
- PTDFs can be visualized on the onelines.

PTDF Calculation

- PTDFs show the linear impact of a power transfer
  - They show what percent of a transfer would appear on each transmission line in the power system
- PTDFs calculated using the factored power flow Jacobian
  - $\Delta \mathbf{x}$ = [J(x*)]-1 $\Delta \mathbf{P}$
  - $\Delta \mathbf{P}$ = change in power injections associated with power transfer
  - $\Delta \mathbf{x}$ = change in system voltages and angles, which are used to calculate flows

Specifying Transfer Direction for PTDF Calculation

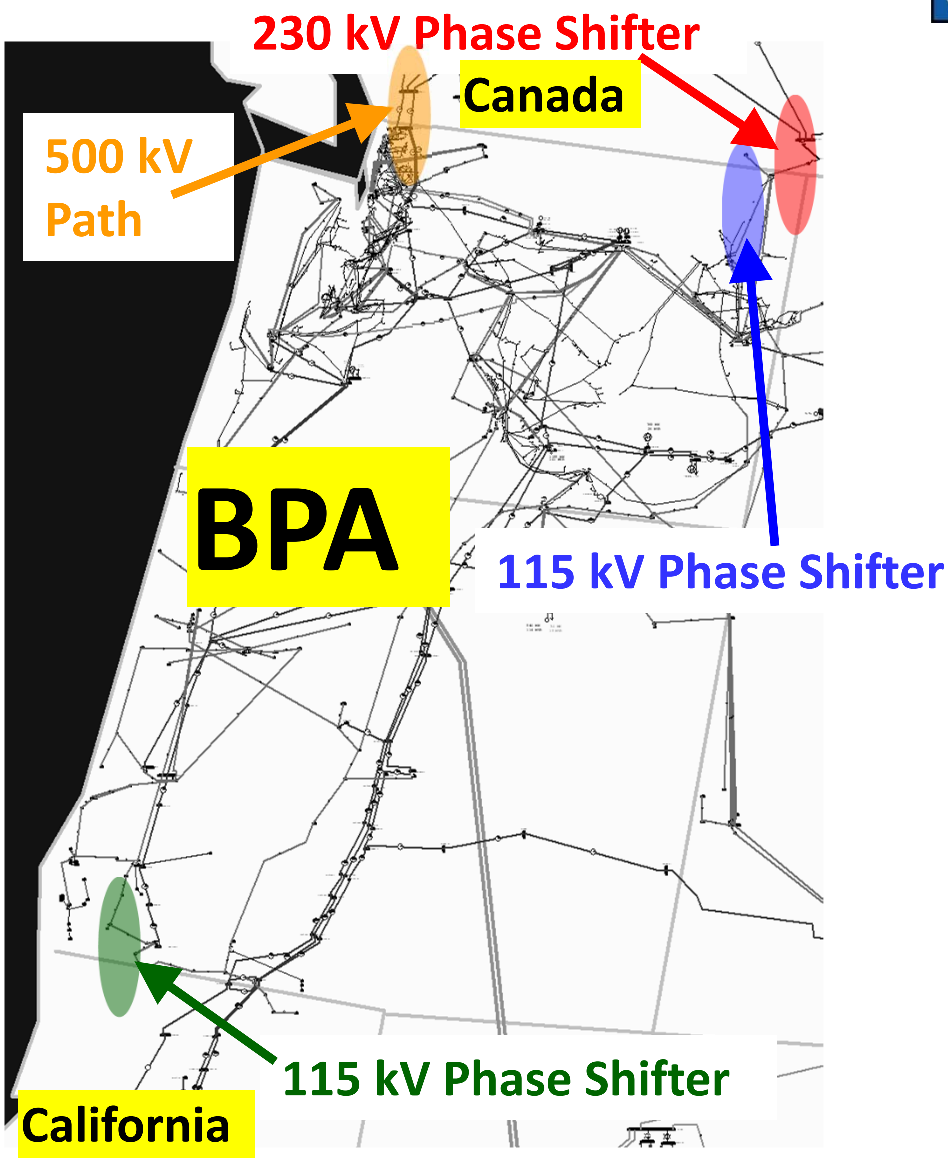
- Must specify a buyer (sink) and a seller (source) of power – a transfer direction
- Options for Buyer and Seller
  - Area, Zone, or Super Area
    - The PTDF calculation will assume that the generators in this region participate according to their participation factors
  - Slack
    - Means all power will come from or go to the slack bus
  - Injection Group
    - Injection groups can include loads and/or generation. Participation is specified for each element of the group
  - Bus
    - All power will come from or go to this bus.

Calculation Method for PTDF Calculation

- Must specify a calculation method
  - Linearized AC – includes the full Jacobian in the calculation, and thus includes losses
    - Note: the PTDF calculation assumes that all losses are made up for by the buyer
    - Exception: if the seller contains the slack bus, then the seller will make up for all losses.
  - Lossless DC – only uses the DC power flow equations, so losses not included
  - Lossless DC with phase shifters – modification to previous that forces change in flow across operating phase shifters to be zero.

Lossless DC with Phase Shifters

- Phase Shifters are often used on lower voltage paths (230 kV or less) with relatively small limits
  - They manage flow on a path that may otherwise see overloads
  - Thus, they constantly show up as "overloaded" when using linear analysis if they are not accounted for
- Example: Border of Canada with Northwestern United States
  - PTDFs between Canada and US without Phase-Shifters
    - 85% on 500 kV Path
    - 15% on Eastern Path
  - PTDF With Phase-Shifters
    - 100% goes on 500 kV Path
    - 0% on Eastern Path



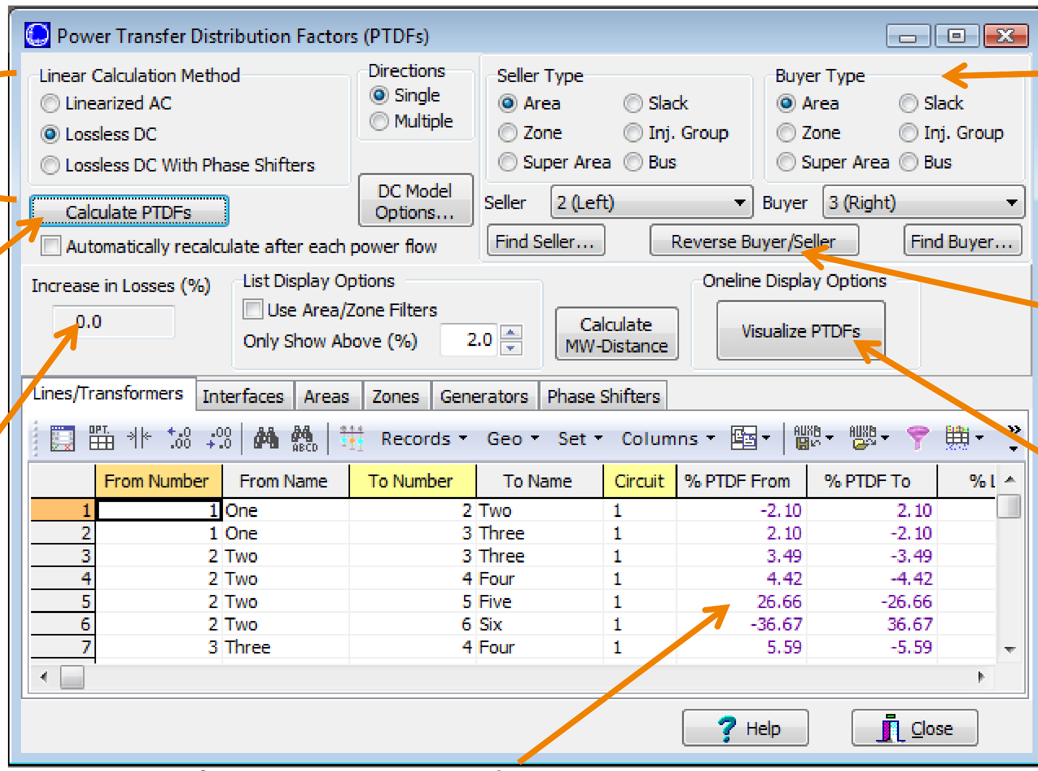
PTDF Display

- Choose **Tools** ribbon tab → **Sensitivities** → **Power Transfer Distribution Factors (PTDFs)**

Select Calculation Method

Select to calculate the PTDFs

Percentage change in system losses



Select seller and buyer

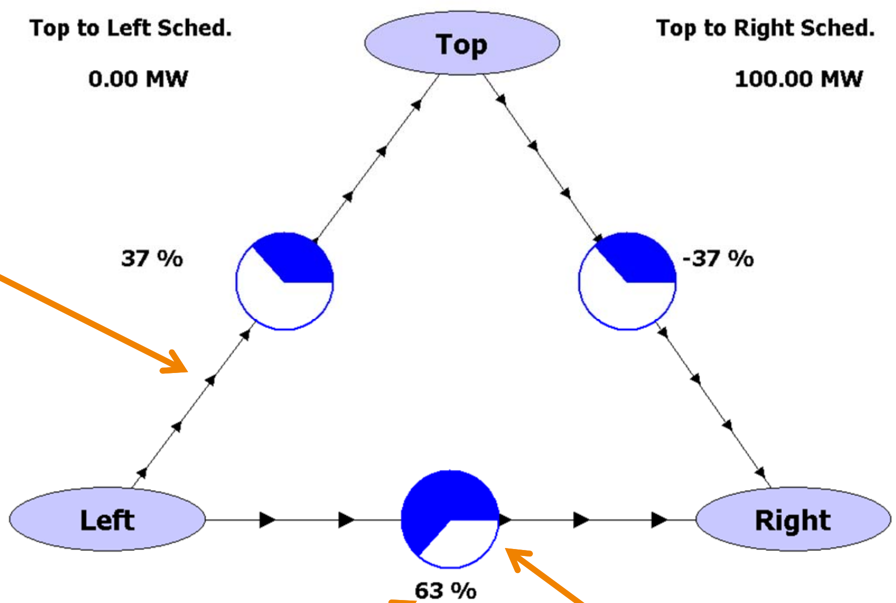
Switches buyer and seller

Visualize PTDFs on oneline. Available if only one oneline is open.

Results expressed as a percentage of the power transfer

PTDFs on the Onelines

Animated arrows indicate percentage of transfer flowing on the interface. A different color may be used to highlight counter-flows

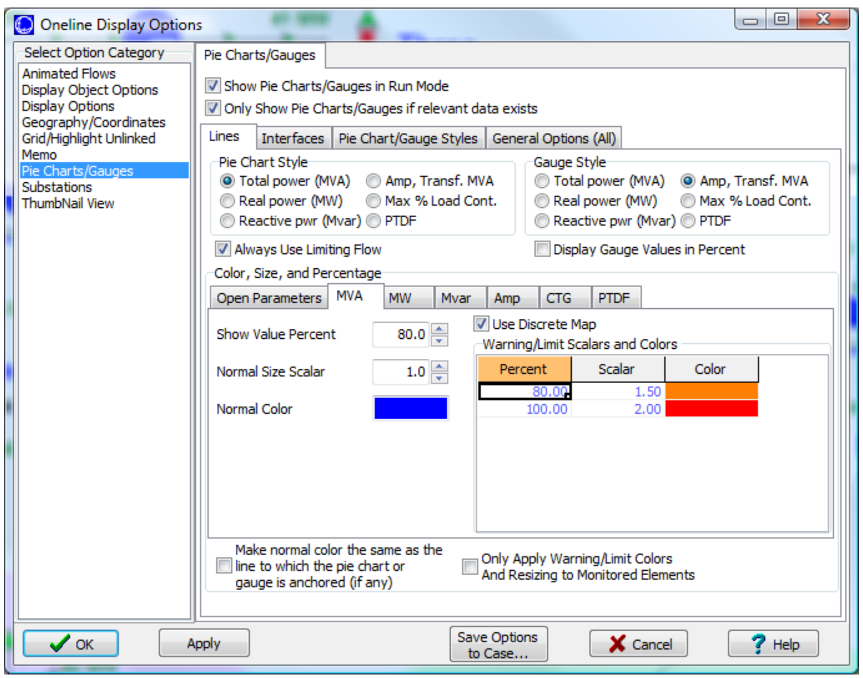


Fields now show percentage of specified transaction flowing through the interface

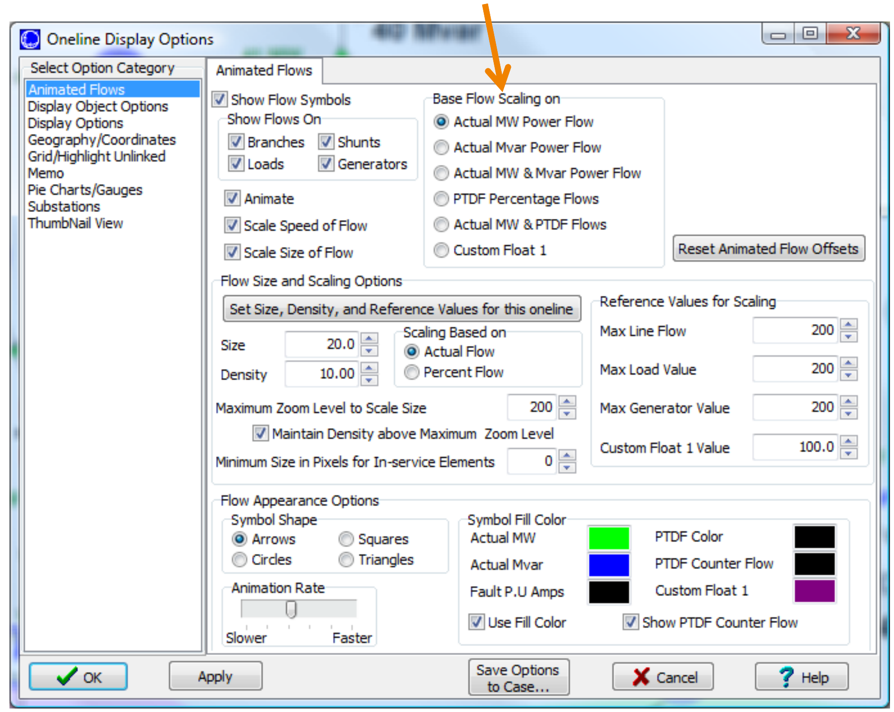
Pie charts indicate %

PTDFs on the Onelines

Using the Oneline Display Options dialog, the size/color of the pie charts (both line and interface) can be conditional, based upon percentage flow through the device



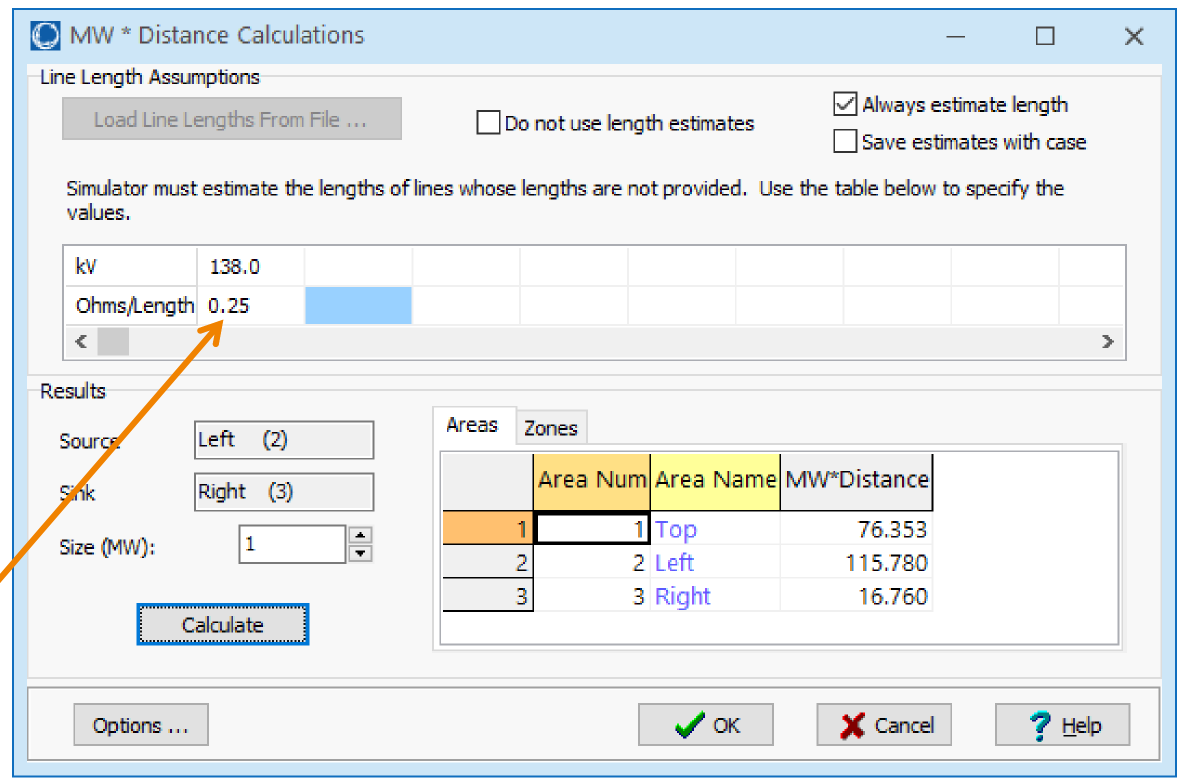
Use to toggle between actual flows and PTDFs (you can also use the oneline local-menu.)



PTDF: MW*Distance

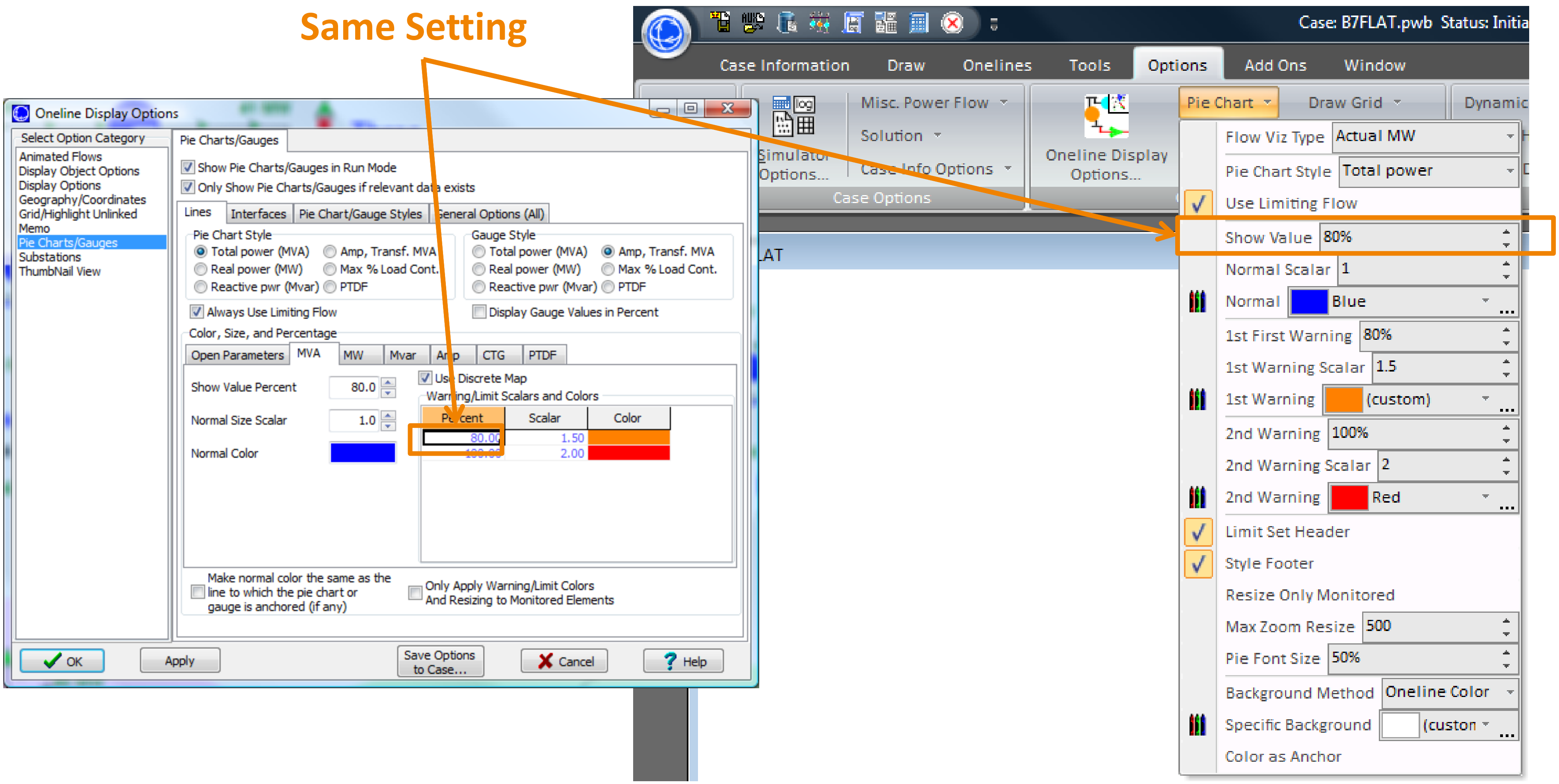
- PTDF results can be used with transmission line lengths to compute the sum of MW*Distance over branches within each Area and Zone for the given PTDF buyer/seller pair.

Length can come from individual line records or Ohm/length estimates by nominal kV



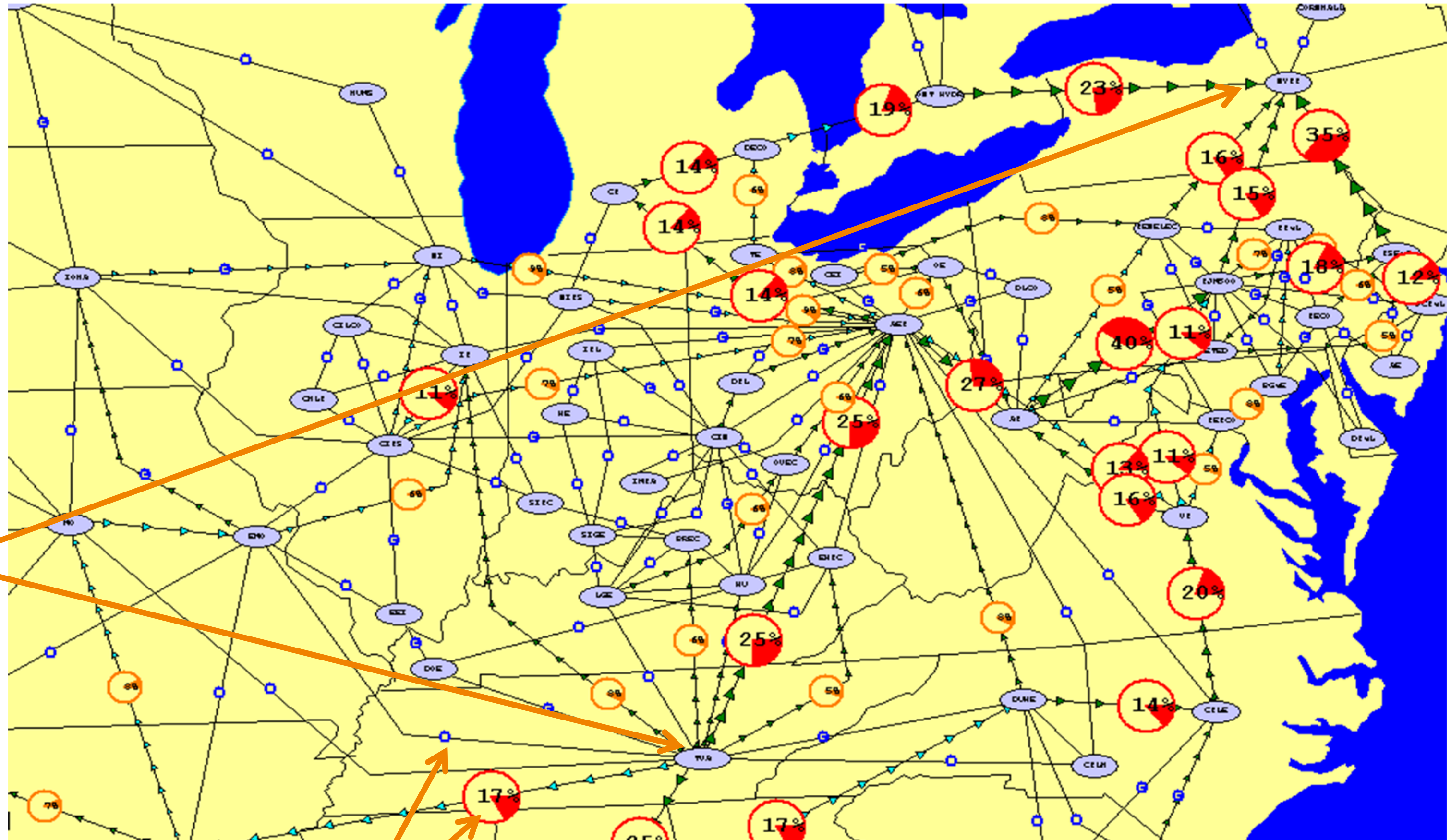
Remember:
Pie Charts Options Toolbar

- Available in **Options** ribbon tab → **Pie Chart**
- Notice that all the settings on the dialog are available



Wide-Area PTDF Visualization

These PTDFs were calculated using a 23,000 bus FERC 715 case for the SERC region



Simulated transfer from TVA to NYPP

Pie charts dynamically change size/color for different PTDF values

Shift Factors

- Sometimes called Generation Shift Factors (GSF) or Transmission Loading Relief (TLR)
- PTDF calculation determines the impact of ONE transfer on MANY lines
- The Shift Factor calculation is exactly the same mathematically, but it determines the impact of MANY transfers on ONE line
- Think about building a table
  - Columns represent many different transfer directions
  - Rows represent many different branches
  - Then the table entry at Row N, Column M is the distribution factor of the Mth transfer on the Nth branch
  - The PTDF calculation determine a column of this table
  - The Shift Factor calculation determines a row of this table

Shift Factor versus PTDFs: Table of Distribution Factors

List of Transfer Directions

List of Lines

	Dir_1		Dir_N	$\cdots$	Dir_{n_d}
Line_1	DF_{11}	$\cdots$	DF_{1N}	$\cdots$	DF_{1n_d}
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
Line_M	DF_{M1}	$\cdots$	DF_{MN}	$\cdots$	DF_{Mn_d}
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
Line_{n_l}	$DF_{n_l 1}$	$\cdots$	$DF_{n_l N}$		$DF_{n_l n_d}$

Shift Factor Calculation For Line M

PTDF Calculation for Direction N

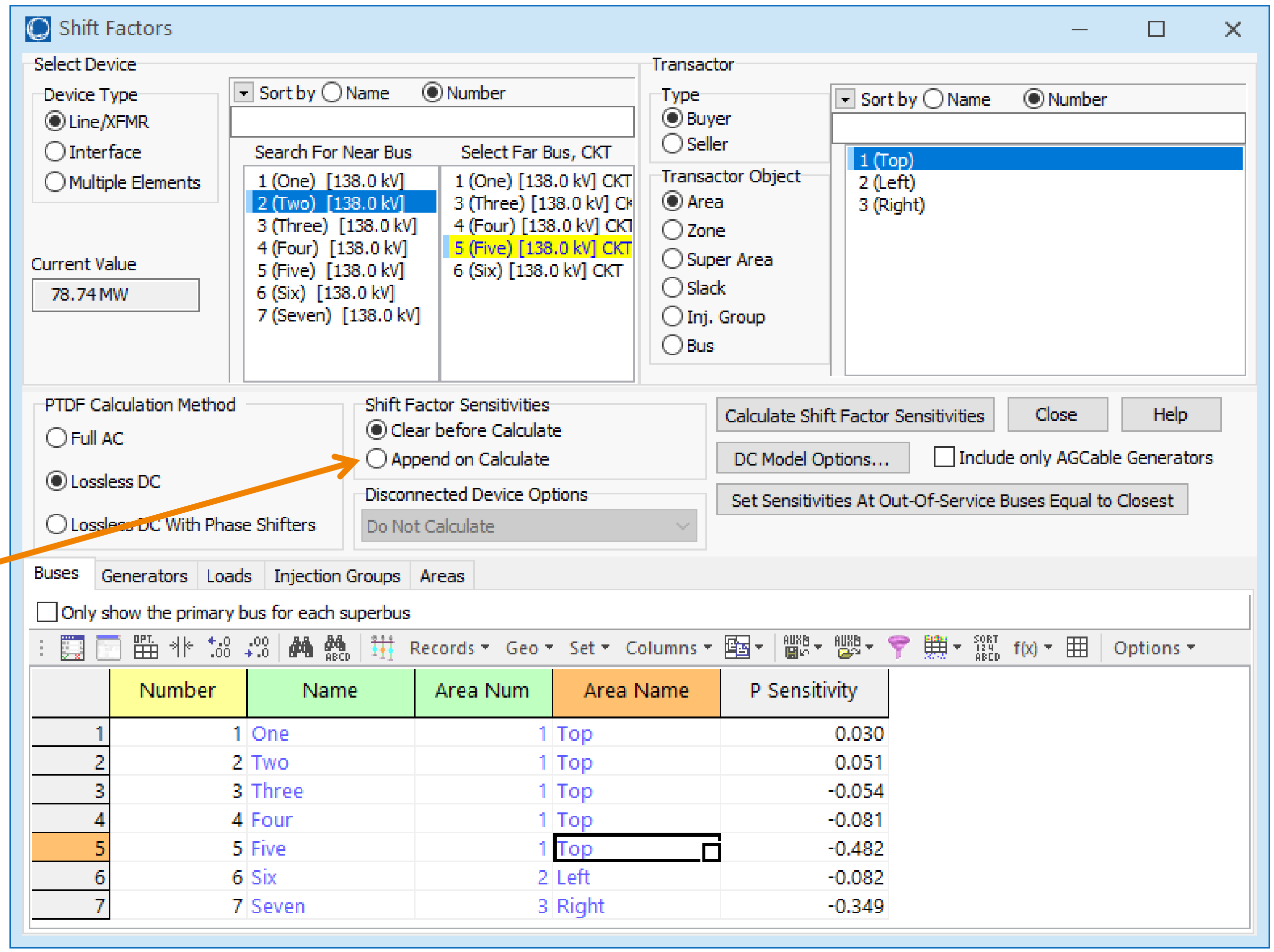
Options for Shift Factor Calculation

- Specify a transmission line or interface
- Specify a calculation method (same as for PTDF)
- To narrow down the choices for directions, specify one end of the transfer (buyer or seller)
  - Shift Factor calculates the impact of transferring power between each bus and the specified end of the transfer.
  - The Area Sensitivities determined will just be a weighted average of the sensitivities for each generator bus in the area (weighted by Participation Factors)

Shift Factors Dialog

- Choose **Tools** ribbon tab → **Sensitivities** → **Shift Factors…**

With **Append on Calculate**, Simulator will retain the highest distribution factor calculated for each bus or area after each calculation



Calculating the whole Table Multiple Direction PTDF

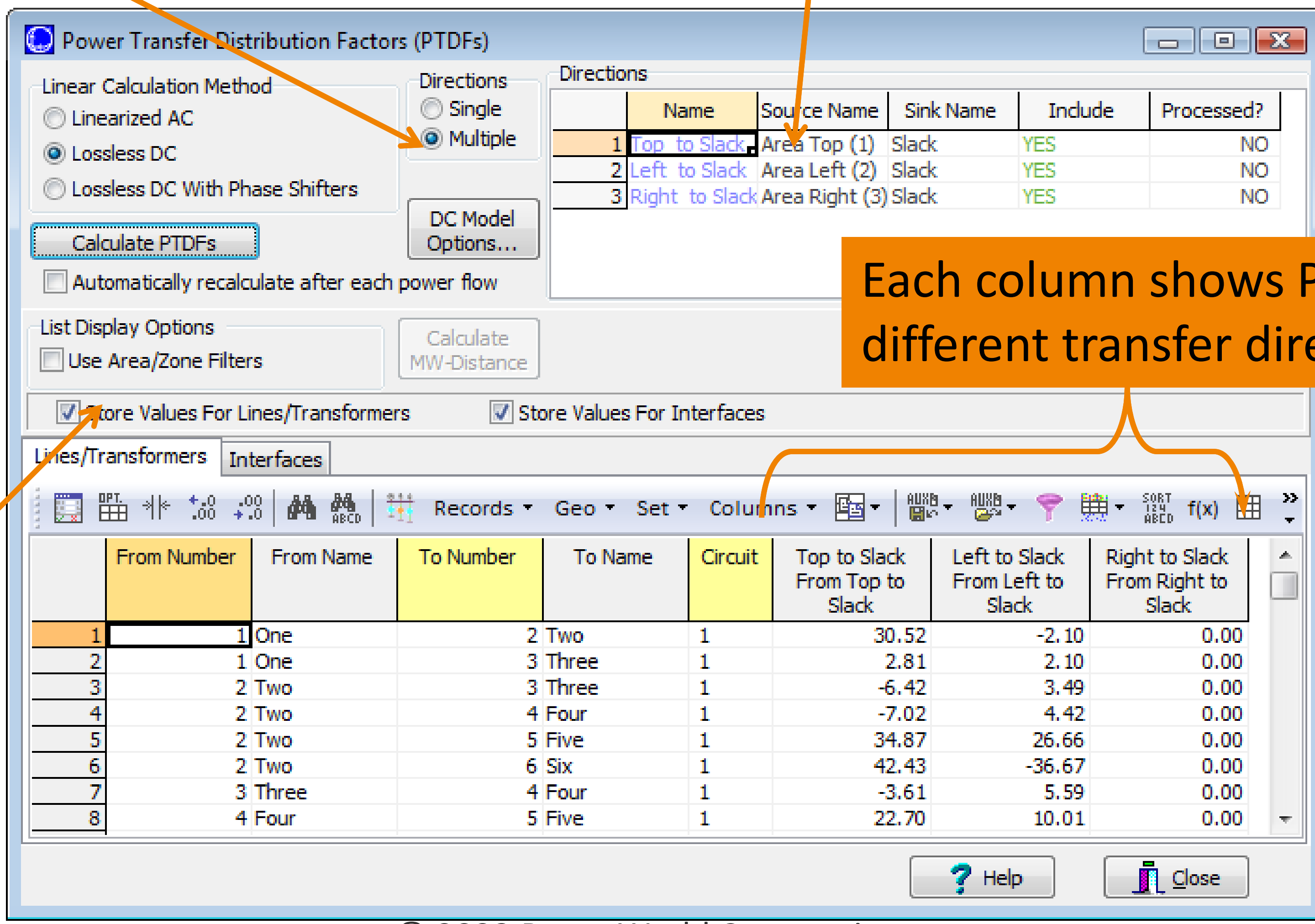
- Simulator also allows you to calculate the entire distribution factor table
- Specify a list of directions
  - Simulator will calculate and display PTDFs for each transfer direction
  - Must be VERY careful. You may ask Simulator to calculate too many numbers for your computer to hold.
    - 20,000 transmission lines and 500 transfer directions means that you must calculate 10 million values (actually it's 20 million because Simulator calculates the PTDF for both directions of flow on the transmission line)
    - Assuming about 20 bytes per value, that's around 400 MB of computer memory

	Dir_1		Dir_N	$\cdots$	Dir_{n_d}
Line_1	DF_{11}	$\cdots$	DF_{1N}	$\cdots$	DF_{1n_d}
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
Line_M	DF_{M1}	$\cdots$	DF_{MN}	$\cdots$	DF_{Mn_d}
$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\ddots$	$\vdots$
Line_{n_l}	$DF_{n_l 1}$	$\cdots$	$DF_{n_l N}$		$DF_{n_l n_d}$

PTDF Display for Multiple Directions

Choose Multiple Directions

Right-click on list display and choose insert or Auto-Insert to specify directions



Each column shows PTDF for a different transfer direction.

To save memory, you can specify whether to store values for only lines or only interfaces

Calculating the whole Table: Multiple Elements Shift Factors

- Multiple Direction PTDFs work best for
  - A small number of Directions
  - A large number of lines/interfaces
- Multiple Elements Shift Factors work best for
  - A large number of Directions/Buses
  - A small number lines/interfaces

Multiple Elements Shift Factors

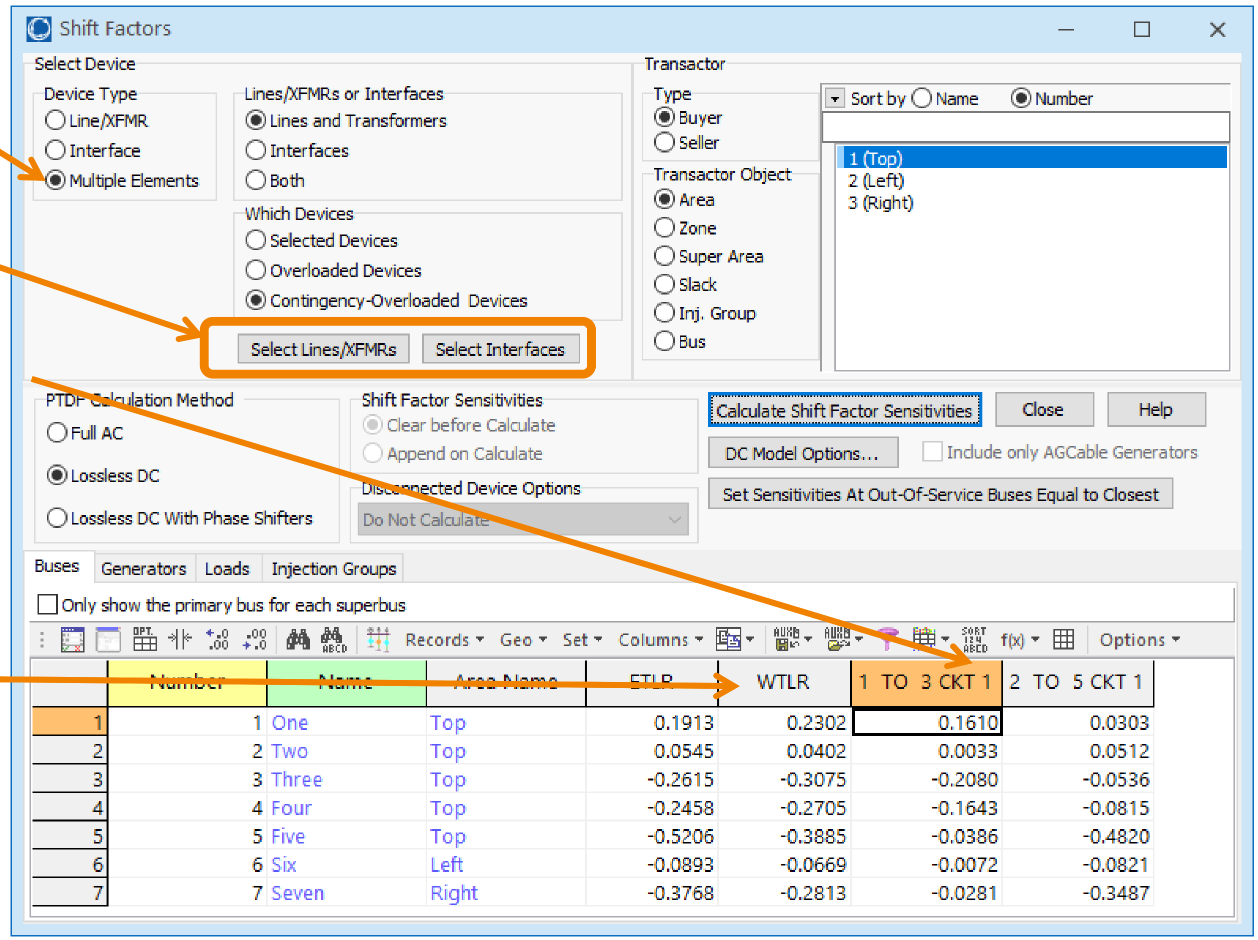
- Allows Calculation of Shift Factors for a set of branches or interfaces

Multiple Elements

Select specific elements

Shift Factors with respect to individual elements

WTLR (Weighted TLR or Shift Factor) shows sensitivity as a weighted sum of MW relief over all elements in the set



Line Outage Distribution Factors (LODFs)

- LODFs are another linearized calculation
  - Calculate the impact of opening (outaging) a transmission branch on all the other branches in the case.
  - Also can calculate the impact of closing in a branch (could call this called a Line Closure Distribution Factor or LCDF)
- Specify a transmission branch, and the calculation determines what percent of the flow on that line will appear on all other transmission lines
  - If the branch was initially open, then the LCDF will calculate what percent of the post-closure flow on the line will appear on other lines

LODF Dialog

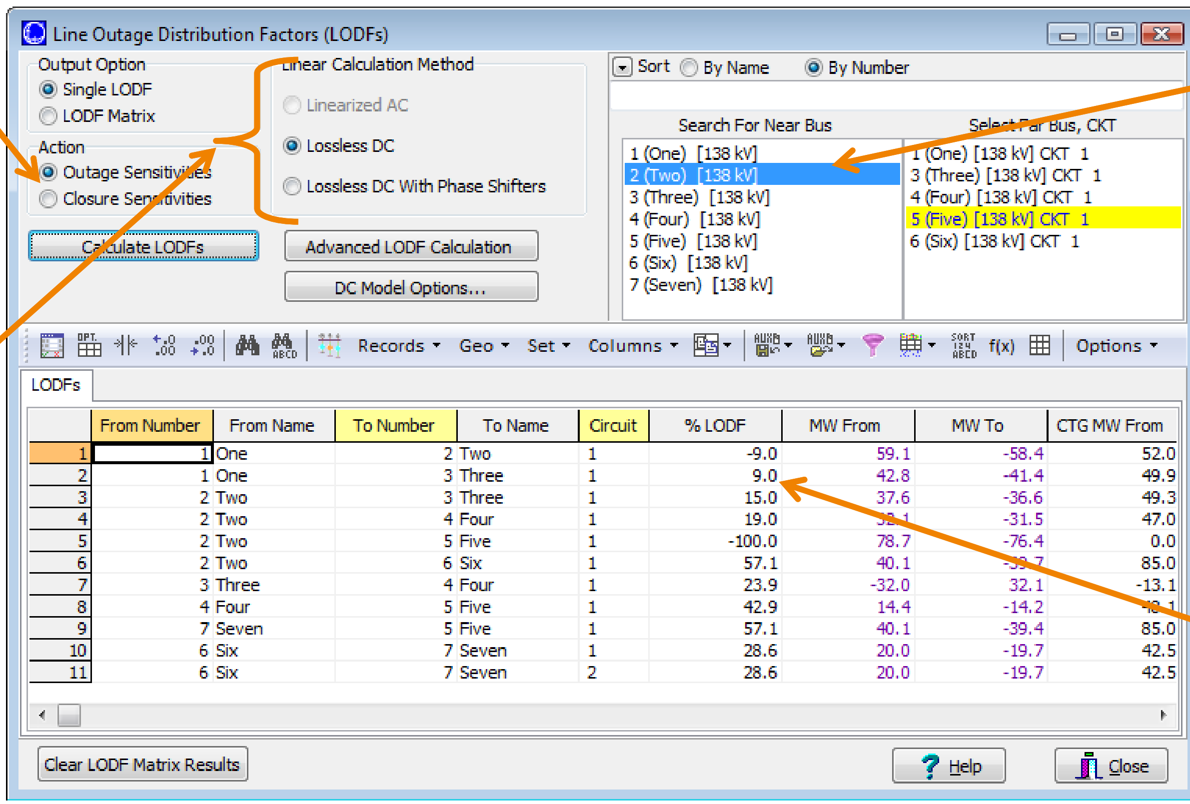
- Choose **Tools** ribbon tab → **Sensitivities** →**Line Outage Distribution Factors (LODFs)**

Action will actually be determined for you

(If the line is presently closed, then it will automatically do an outage sensitivity)

Select the transmission branch

Select Calculation Method to Use



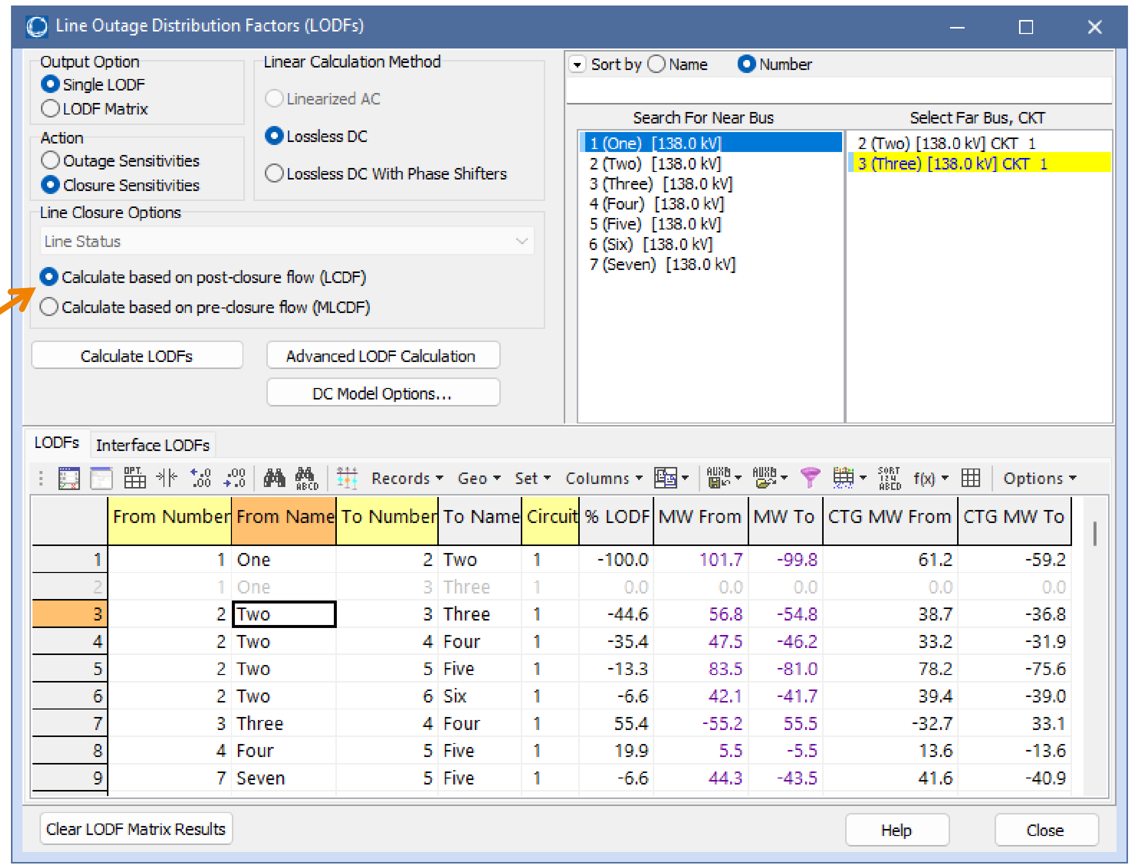
	From Number	From Name	To Number	To Name	Circuit	% LODF	MW From	MW To	CTG MW From
1	1	One	2	Two	1	-9.0	59.1	-58.4	52.0
2	1	One	3	Three	1	9.0	42.8	-41.4	49.9
3	2	Two	3	Three	1	15.0	37.6	-36.6	49.3
4	2	Two	4	Four	1	19.0	[illegible]	-31.5	47.0
5	2	Two	5	Five	1	-100.0	78.7	-76.4	0.0
6	2	Two	6	Six	1	57.1	40.1	[illegible]	85.0
7	3	Three	4	Four	1	23.9	-32.0	32.1	-13.1
8	4	Four	5	Five	1	42.9	14.4	-14.2	[illegible]
9	7	Seven	5	Five	1	57.1	40.1	-39.4	85.0
10	6	Six	7	Seven	1	28.6	20.0	-19.7	42.5
11	6	Six	7	Seven	2	28.6	20.0	-19.7	42.5

LODF values in percent (or LCDF)

Closure Sensitivities

- Closure sensitivity computes % of the estimated post-closure flow on the selected (open) line that will show up on other lines and interfaces.

Calculation based on post-closure or pre-closure flow



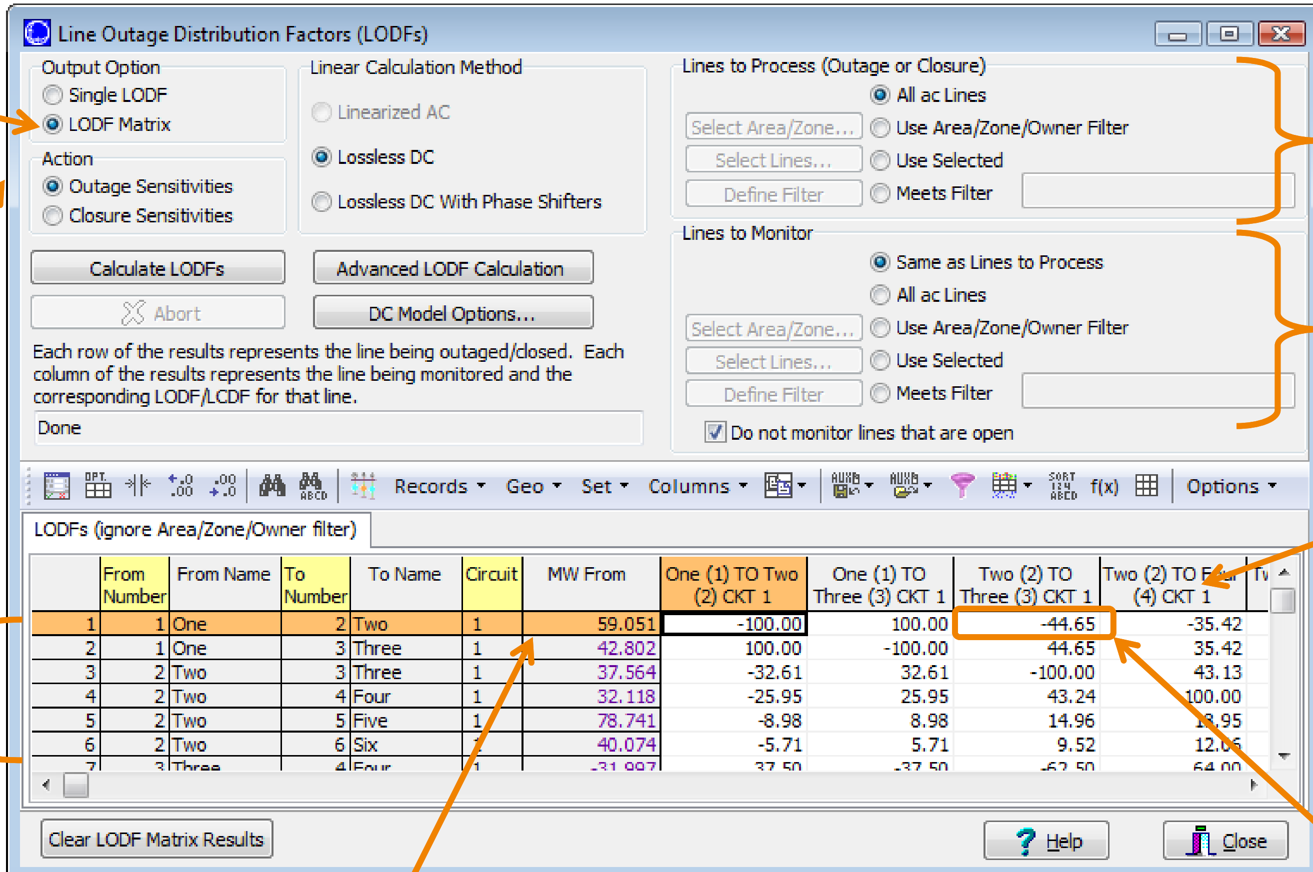
	From Number	From Name	To Number	To Name	Circuit	% LODF	MW From	MW To	CTG MW From	CTG MW To
1	1	One	2	Two	1	-100.0	101.7	-99.8	61.2	-59.2
2	1	One	3	Three	1	0.0	0.0	0.0	0.0	0.0
3	2	Two	3	Three	1	-44.6	56.8	-54.8	38.7	-36.8
4	2	Two	4	Four	1	-35.4	47.5	-46.2	33.2	-31.9
5	2	Two	5	Five	1	-13.3	83.5	-81.0	78.2	-75.6
6	2	Two	6	Six	1	-6.6	42.1	-41.7	39.4	-39.0
7	3	Three	4	Four	1	55.4	-55.2	55.5	-32.7	33.1
8	4	Four	5	Five	1	19.9	5.5	-5.5	13.6	-13.6
9	7	Seven	5	Five	1	-6.6	44.3	-43.5	41.6	-40.9

LODF Matrix

Select LODF Matrix

Type of sensitivity

Lines to outage/ close



Select lines to outage/close

Select lines to monitor

Lines to monitor

LODF on Line 2-3 for outage of Line 1-2

Present MW flow on line

Outage Transfer Distribution Factors (OTDFs)

- Not a standalone calculation, but used within other Simulator tools
  - Available Transfer Capability (ATC)
  - PTDF for an interface with Contingency Element(s)
  - Contingency Analysis: Calculate OTDFs from PTDFs
- The setup for the calculation
  - Study a transfer between a seller and buyer
  - Monitor the flow on line M
  - What happens after an outage of line C?
- OTDF: the percent of the transfer that will flow on Line M AFTER the outage of line C
- Outage MW (OMW): The MW flow on line M after line C is outaged
- Calculate OMW and OTDF from by using the present flow on the lines and PTDFs and LODFs

OTDF, OMW Calculation

- Values we already know

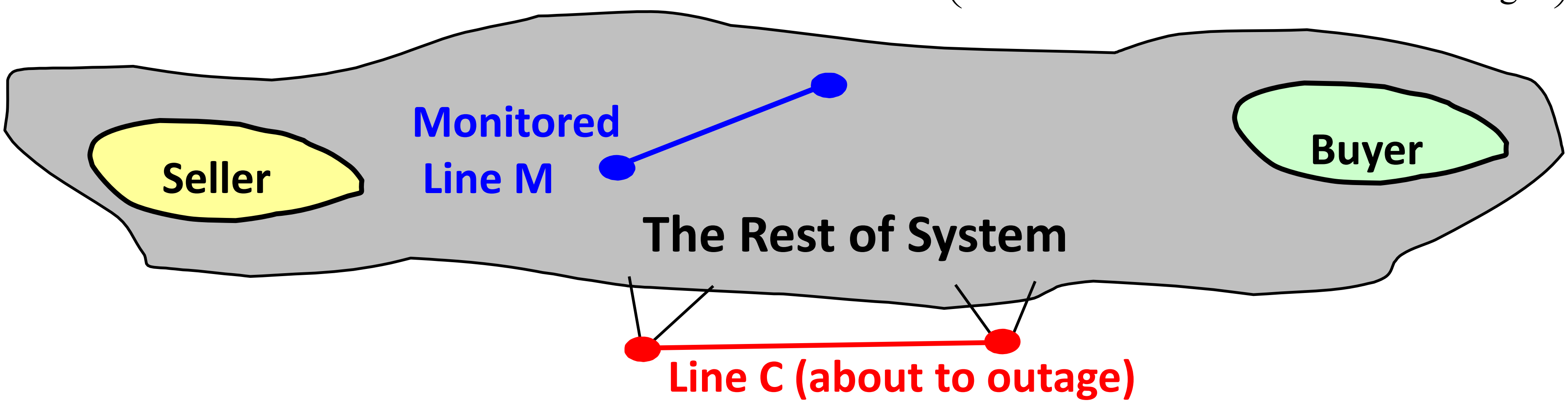
$$PTDF_M = \text{PTDF for the transfer direction on line M}$$

$$PTDF_C = \text{PTDF for the transfer direction on line C}$$

$$MW_M = (\text{present MW flow on monitored line M})$$

$$MW_C = (\text{present MW flow on contingent line C})$$

$$LODF_{M,C} = \begin{pmatrix} \text{the percent of flow on line C that will} \\ \text{move over to line M if Line C is outaged} \end{pmatrix}$$



- Calculate the OTDF and OMW values from this

$$OMW_{M,C} = MW_M + LODF_{M,C} * MW_C$$

$$OTDF_{M,C} = PTDF_M + LODF_{M,C} * PTDF_C$$

OTDF and OMW calculation for multiple line outages

- A similar calculation can be done when trying to include multiple-line outage OTDFs
  - Finds the percent of a transfer that will flow on Line M AFTER the outage of lines 1, 2, …
- Simulator handles these multiple outages internally

Flow and Voltage Sensitivities

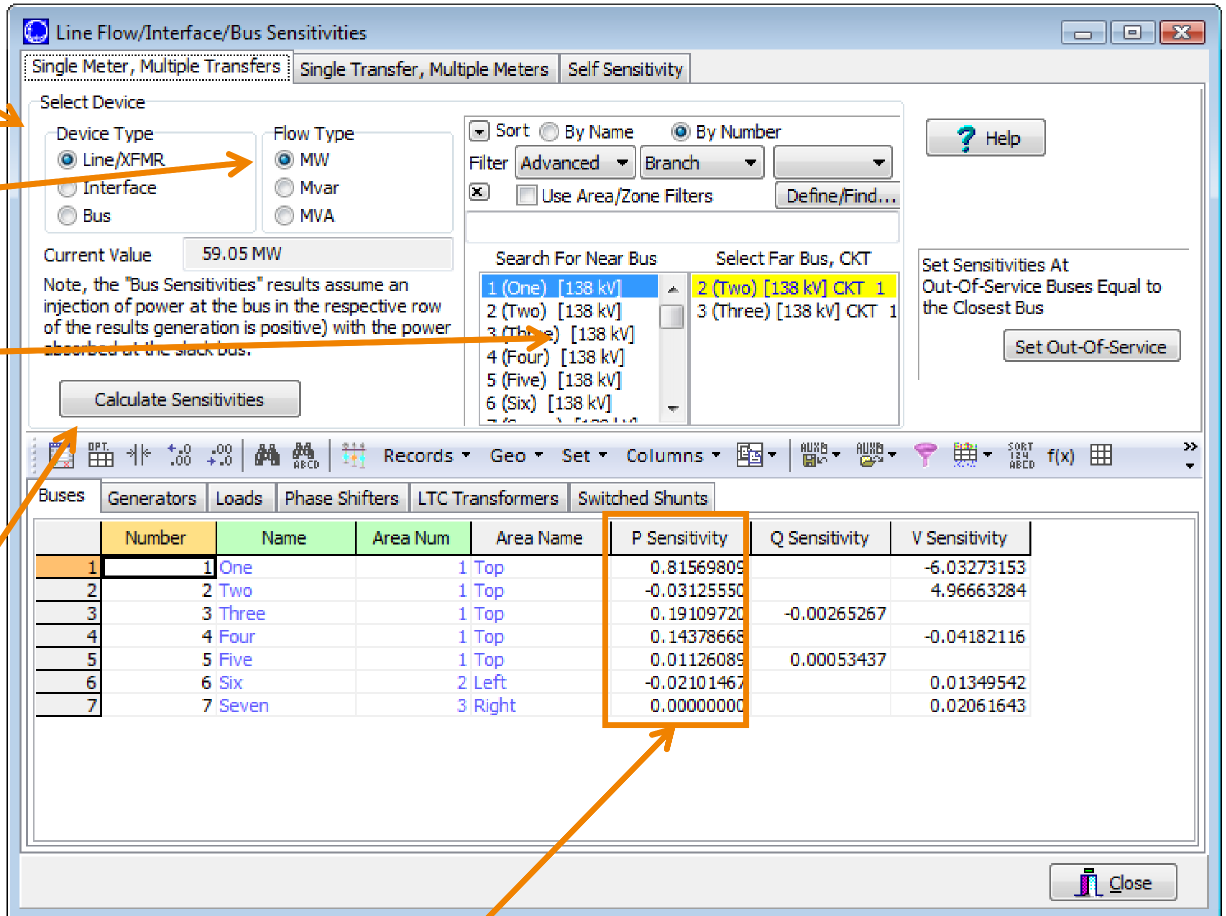
- Choose **Tools** ribbon tab → **Sensitivities** → **Flow and Voltage Sensitivities to** bring up the Line Flow/ Interface/Bus Sensitivities dialog
- **Single Meter, Multiple Transfers**: Calculates the sensitivity of various values to an injection of real or reactive power, or a change in a regulated bus voltage setpoint
  - If not specified, these calculations assume that the absorption of MW/Mvars occurs at the ***island slack bus***
  - Line or Interface MW flow sensitivities → $\frac{dP_{Flow}}{d\mathbf{P}_{\mathbf{injection}}}, \frac{dP_{Flow}}{d\mathbf{Q}_{\mathbf{injection}}}$
  - Line or Interface MVAR flow sensitivities → $\frac{dQ_{Flow}}{d\mathbf{P}_{\mathbf{injection}}}, \frac{dQ_{Flow}}{d\mathbf{Q}_{\mathbf{injection}}}$
  - Line or Interface MVA flow sensitivities → $\frac{dS_{Flow}}{d\mathbf{P}_{\mathbf{injection}}}, \frac{dS_{Flow}}{d\mathbf{Q}_{\mathbf{injection}}}$
  - Bus voltage sensitivities → $\frac{dV_{Bus}}{d\mathbf{P}_{\mathbf{injection}}}, \frac{dV_{Bus}}{d\mathbf{Q}_{\mathbf{injection}}}$
  - Generator Mvar sensitivities → $\frac{dQ_{Gen}}{d\mathbf{P}_{\mathbf{injection}}}, \frac{dQ_{Gen}}{d\mathbf{Q}_{\mathbf{injection}}}$

Flows and Voltage Sensitivities

Select Device and Flow or Voltage Type

Select Monitored Device

Click Calculate Sensitivities

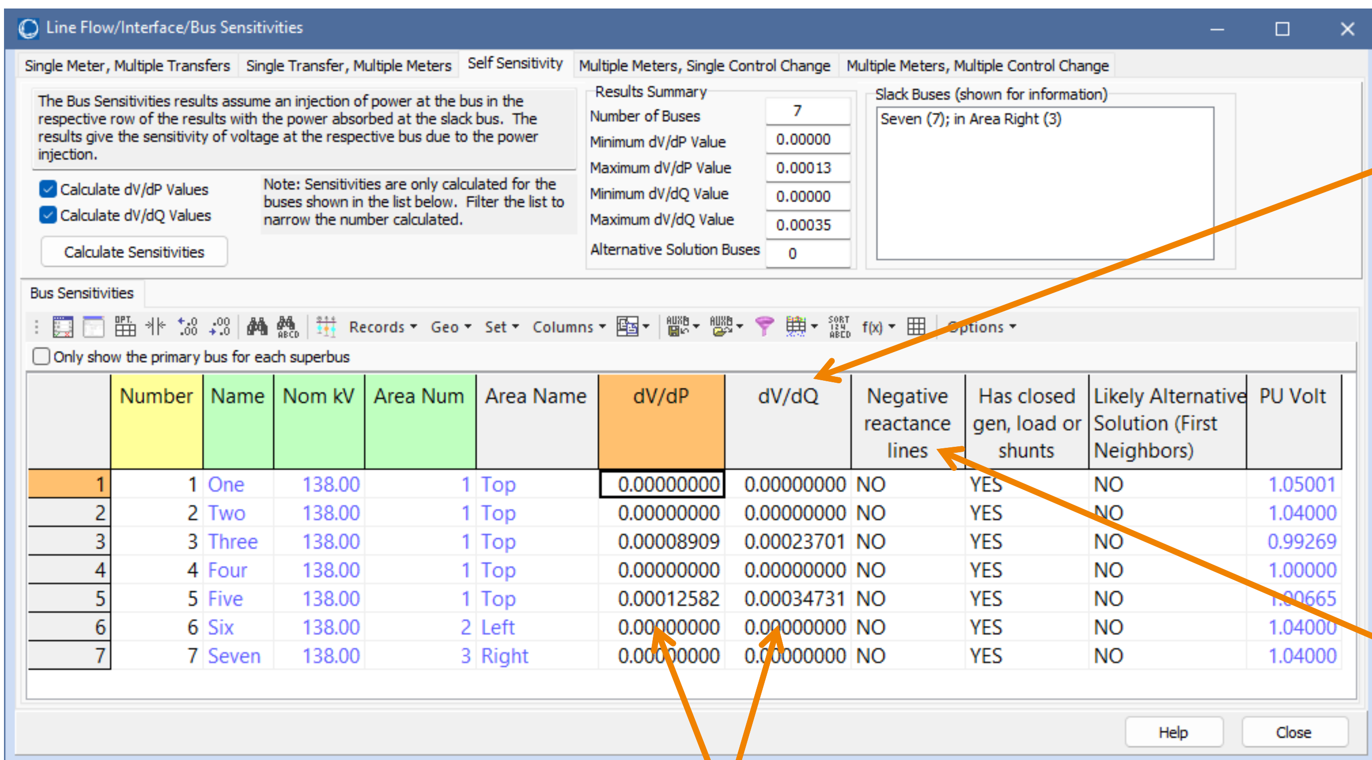


	Number	Name	Area Num	Area Name	P Sensitivity	Q Sensitivity	V Sensitivity
1	1	One	1	Top	0.81569809		-6.03273153
2	2	Two	1	Top	-0.03125550		4.96663284
3	3	Three	1	Top	0.19109720	-0.00265267	
4	4	Four	1	Top	0.14378668		-0.04182116
5	5	Five	1	Top	0.01126089	0.00053437	
6	6	Six	2	Left	-0.02101467		0.01349542
7	7	Seven	3	Right	0.00000000		0.02061643

Represents how the Line 1-2's MW will change for a 1 MW injection of Power at respective bus (with the power absorbed at the slack bus)

Flow and Voltage Sensitivities

- **Self Sensitivity**: sensitivity of voltage at each bus for P or Q injection at that bus (withdrawn at the island slack)



	Number	Name	Nom kV	Area Num	Area Name	dV/dP	dV/dQ	Negative reactance lines	Has closed gen, load or shunts	Likely Alternative Solution (First Neighbors)	PU Volt
1	1	One	138.00	1	Top	0.00000000	0.00000000	NO	YES	NO	1.05001
2	2	Two	138.00	1	Top	0.00000000	0.00000000	NO	YES	NO	1.04000
3	3	Three	138.00	1	Top	0.00008909	0.00023701	NO	YES	NO	0.99269
4	4	Four	138.00	1	Top	0.00000000	0.00000000	NO	YES	NO	1.00000
5	5	Five	138.00	1	Top	0.00012582	0.00034731	NO	YES	NO	1.00665
6	6	Six	138.00	2	Left	0.00000000	0.00000000	NO	YES	NO	1.04000
7	7	Seven	138.00	3	Right	0.00000000	0.00000000	NO	YES	NO	1.04000

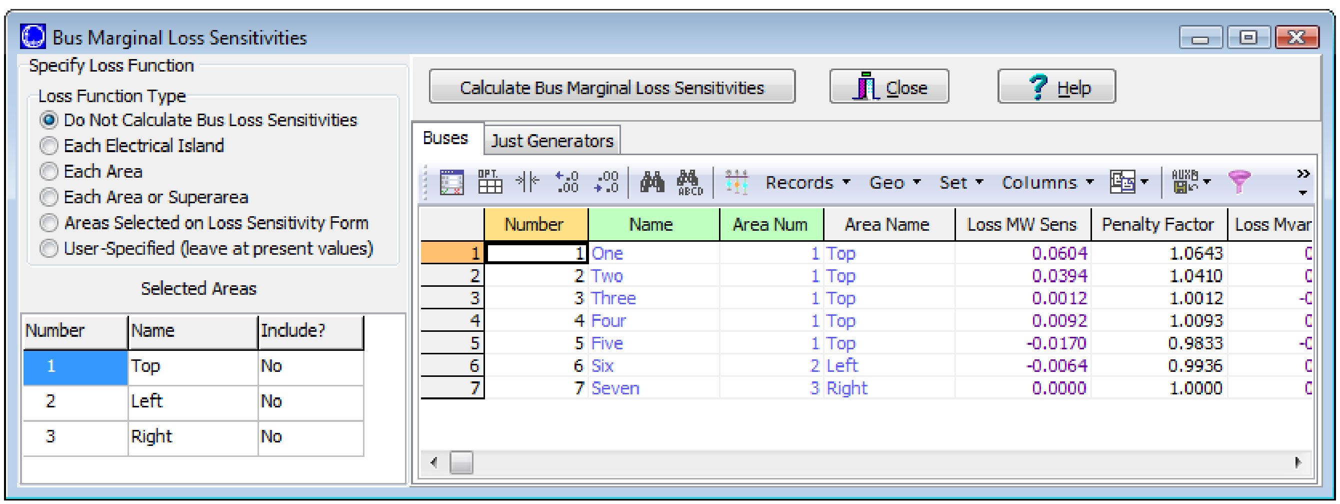
dV/dQ is a measure of how close a bus is to QV instability; negative values may indicate a low-voltage solution

Negative dV/dQ is normal if bus is incident to a negative reactance branch (e.g. series capacitor or 3-winding xfr)

Regulated buses usually have zero values

Loss Sensitivities

- Choose **Tools** ribbon tab → **Sensitivities** → **Loss Sensitivities** to bring up the Bus Marginal Loss Sensitivities dialog
- This models an injection of 1.0 MW at a bus with this power being absorbed at the island slack bus
- The **Loss MW Sens** value for each bus represents how much the losses as specified by the **Loss Function Type** will increase for the 1 MW injection at the respective bus



Loss Sensitivities

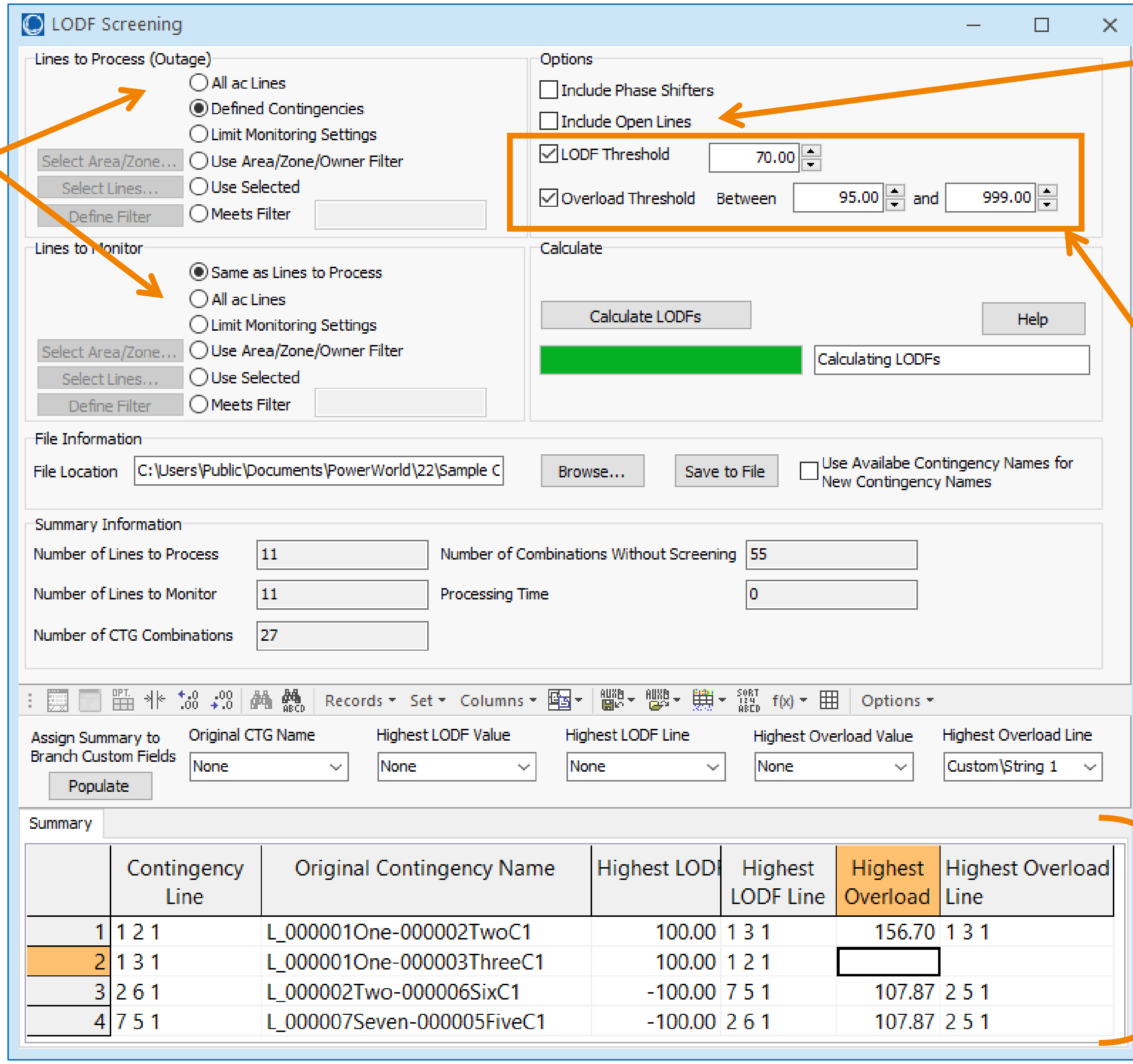
- Penalty Factor Column equals 1/(1 – Loss MW Sens)
- Loss Function Types
  - Do not calculate – All Loss MW Sens values will be zero
  - Each Electrical Island – how do losses change in the island
  - Each Area – For each bus it calculates how the losses in the bus' area will change (Note: this means that sensitivities at buses in two different areas can not be directly compared because they are referenced to different losses)
  - Each Area or Super Area – same as Each Area, but if a Super Area exists it will use this instead (Note: this means that sensitivities at buses in two different areas can not be directly compared because they are referenced to different losses)
  - Areas Selected on Loss Sensitivity Form – Calculates how the losses in the selected areas will change
  - User-Specified – Values will never be recalculated. Also the Loss MW Sens column will become enterable (blue) on the bus displays.

LODF Screening

- Can help identify pairs of contingencies that are significant without actually solving all of the contingencies
- Methods based on the technical paper - C. Matthew Davis and Thomas J. Overbye, "Multiple Element Screening," *IEEE Transactions on Power Systems*, vol. 26, no. 3, pp. 1294-1301, Aug. 2011

LODF Screening

Choose sets of lines to Outage and to Monitor



Optionally use LCDF for Open Lines

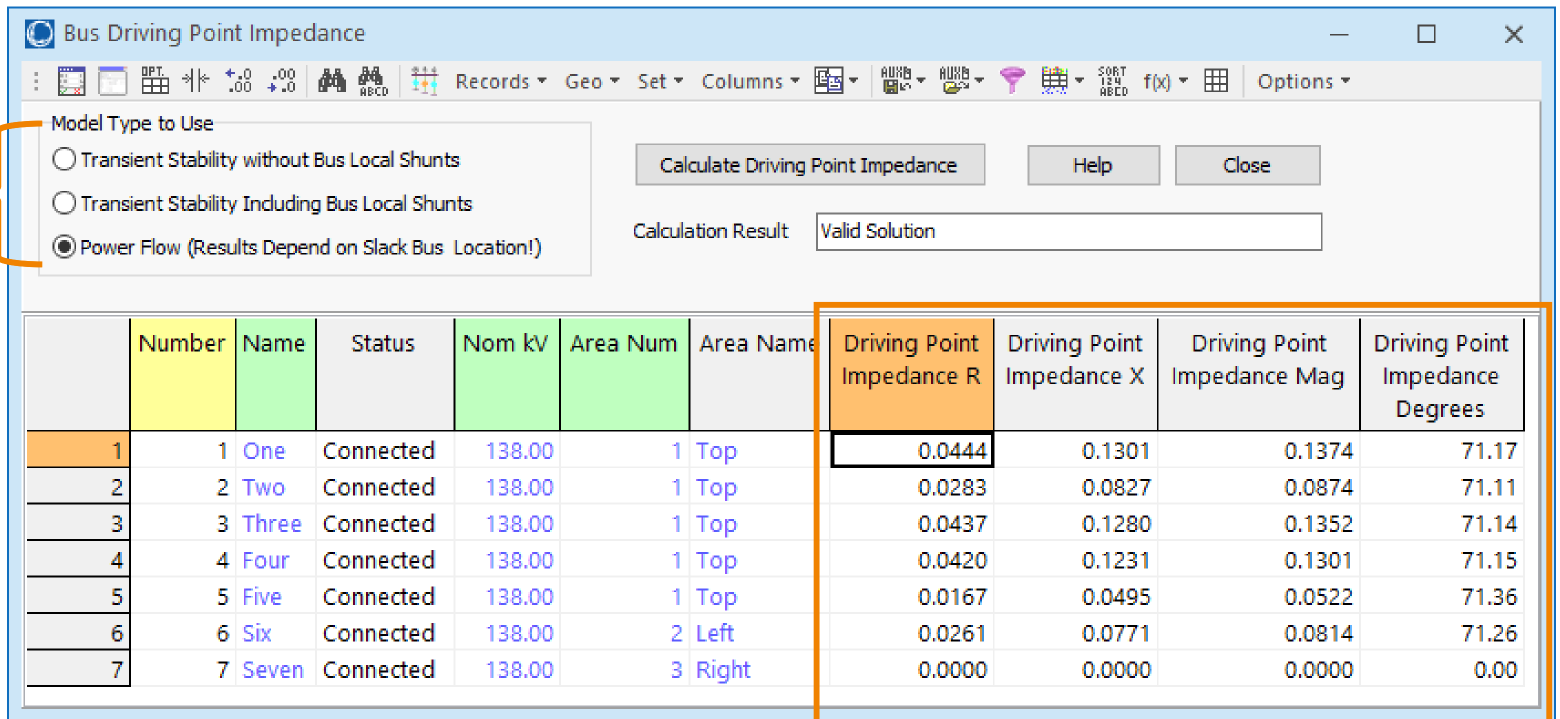
Screening thresholds (LODF% and/or Limit%)

Results (columns populated according to options selected above)

Driving Point Impedances

- Compute impedance at each bus, looking into the system

Power Flow Model uses Y-bus; Transient Stability options include internal impedances of generators and loads



	Number	Name	Status	Nom kV	Area Num	Area Name	Driving Point Impedance R	Driving Point Impedance X	Driving Point Impedance Mag	Driving Point Impedance Degrees
1	1	One	Connected	138.00	1	Top	0.0444	0.1301	0.1374	71.17
2	2	Two	Connected	138.00	1	Top	0.0283	0.0827	0.0874	71.11
3	3	Three	Connected	138.00	1	Top	0.0437	0.1280	0.1352	71.14
4	4	Four	Connected	138.00	1	Top	0.0420	0.1231	0.1301	71.15
5	5	Five	Connected	138.00	1	Top	0.0167	0.0495	0.0522	71.36
6	6	Six	Connected	138.00	2	Left	0.0261	0.0771	0.0814	71.26
7	7	Seven	Connected	138.00	3	Right	0.0000	0.0000	0.0000	0.00

Results show R, X, Magnitude, and Angle of impedance from each bus; slack bus is always zero using Power Flow model

Line Loading Replicator

- Available from **Tools** ribbon tab → **Line Loading Replicator**
- Uses linear transfer sensitivities to calculate injection changes required to achieve desired MW flow on a selected line
- Injection groups used to select the generators and loads that can participate in the injection changes
- Net injection change is zero; same amount of MW injected into the system as taken out of the system
- Generator and load min and max always enforced
- Injection changes can be implemented in the power flow case to determine the actual impact of the changes

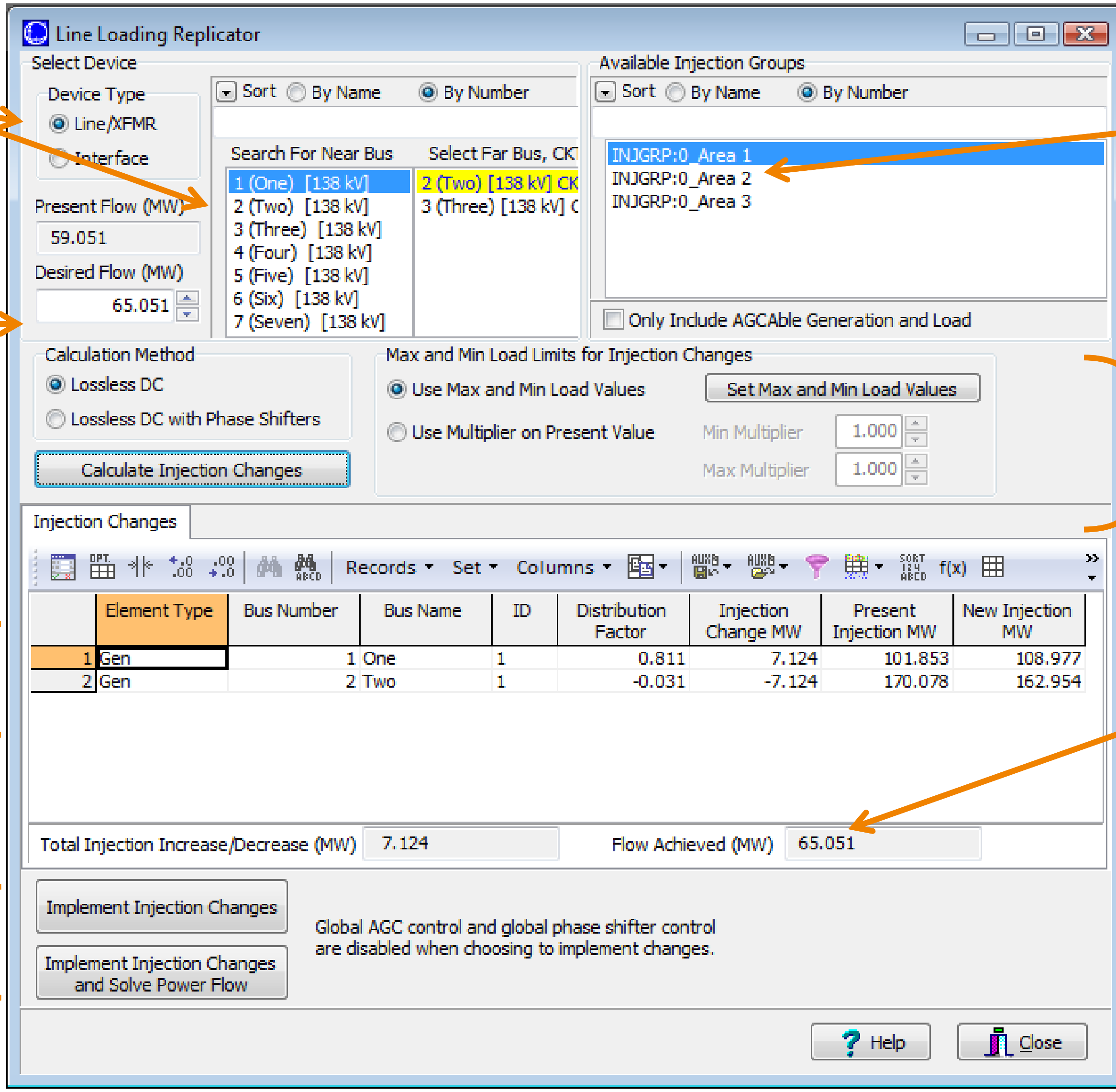
Line Loading Replicator Dialog

Choose the device

Set the Desired Flow

Participating elements and required injection changes

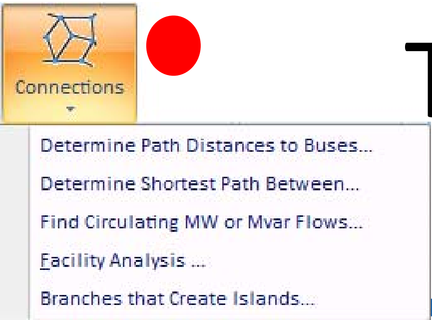
Implement injection changes in the case



Select the injection group that contains participants

Define Max and Min load limits

MW Flow value that can be achieved on selected device



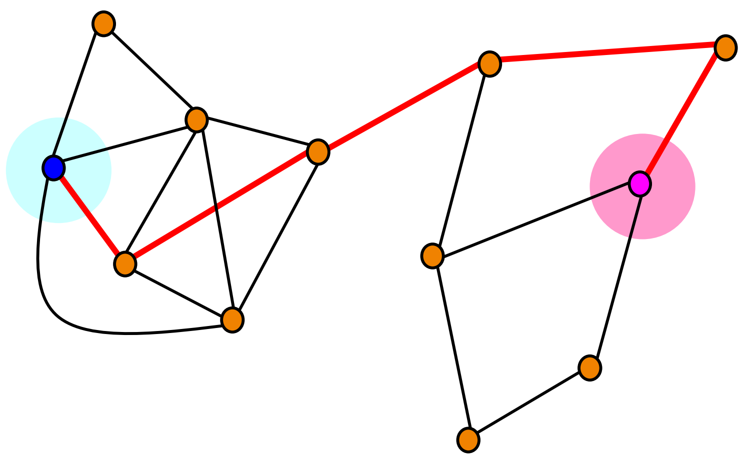
Tools: Other Ribbon Group Connections Menu

- Features in this menu analyze the connectivity of the power system model
  - Determine Path Distances to Buses…
    - Determine the path distance at each bus to a particular part of the system
  - Determine Shortest Path Between…
    - Find the shortest path between points in the network
  - Facility Analysis…
    - Find the minimum number of branches to remove to separate two parts of the network
  - Branches that Create Islands…
    - Find a list of branches that if removed will split the network into two islands.

Tools in Connections Menu: Graph Analysis Tools

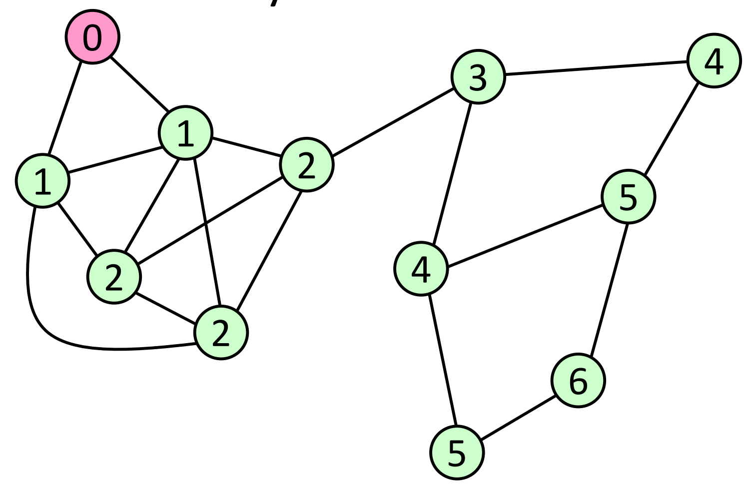
Determine Shortest Path Between

Result: Returns a list of branches



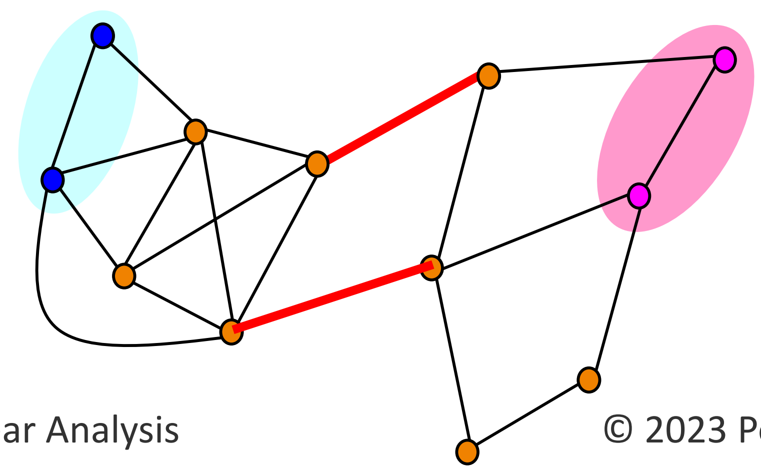
Determine Path Distances to Buses

Result: Labels every Bus



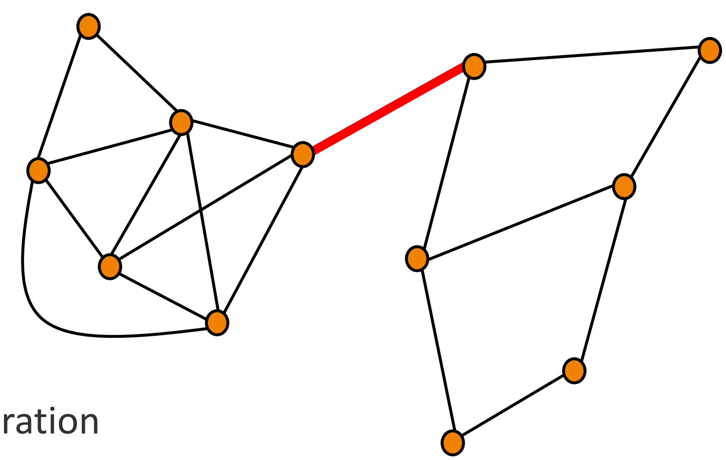
Facility Analysis

Result: Returns a list of branches



Branches that Create Islands

Result: Returns a list of branches



Determine Path Distances From Bus or Group

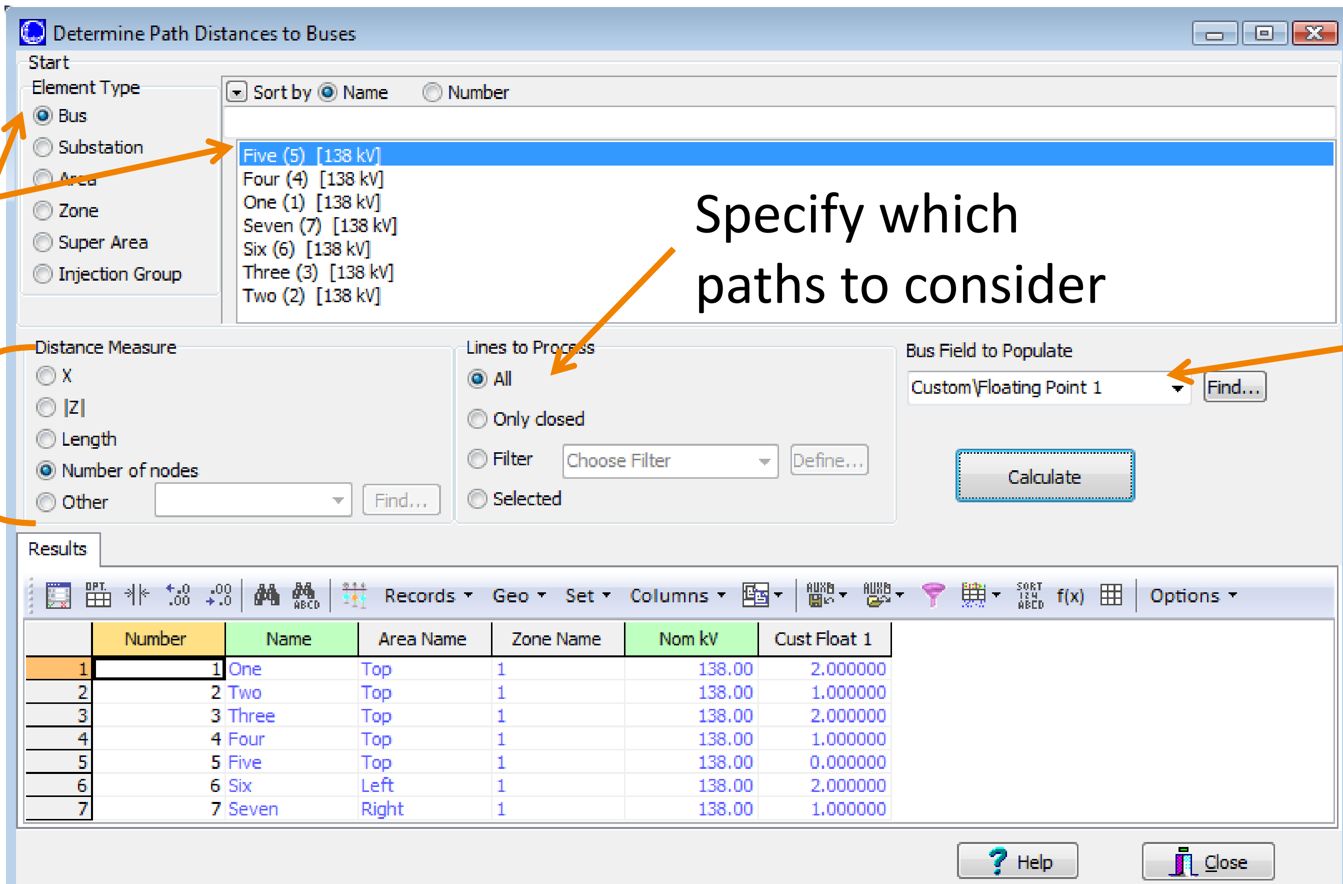
- This tool allows you to choose a single bus or a group of buses, and then determine the distance from that to all the other buses in the group

Choose "Start" element

Specify which paths to consider

Populate as a bus field

Choose distance measure



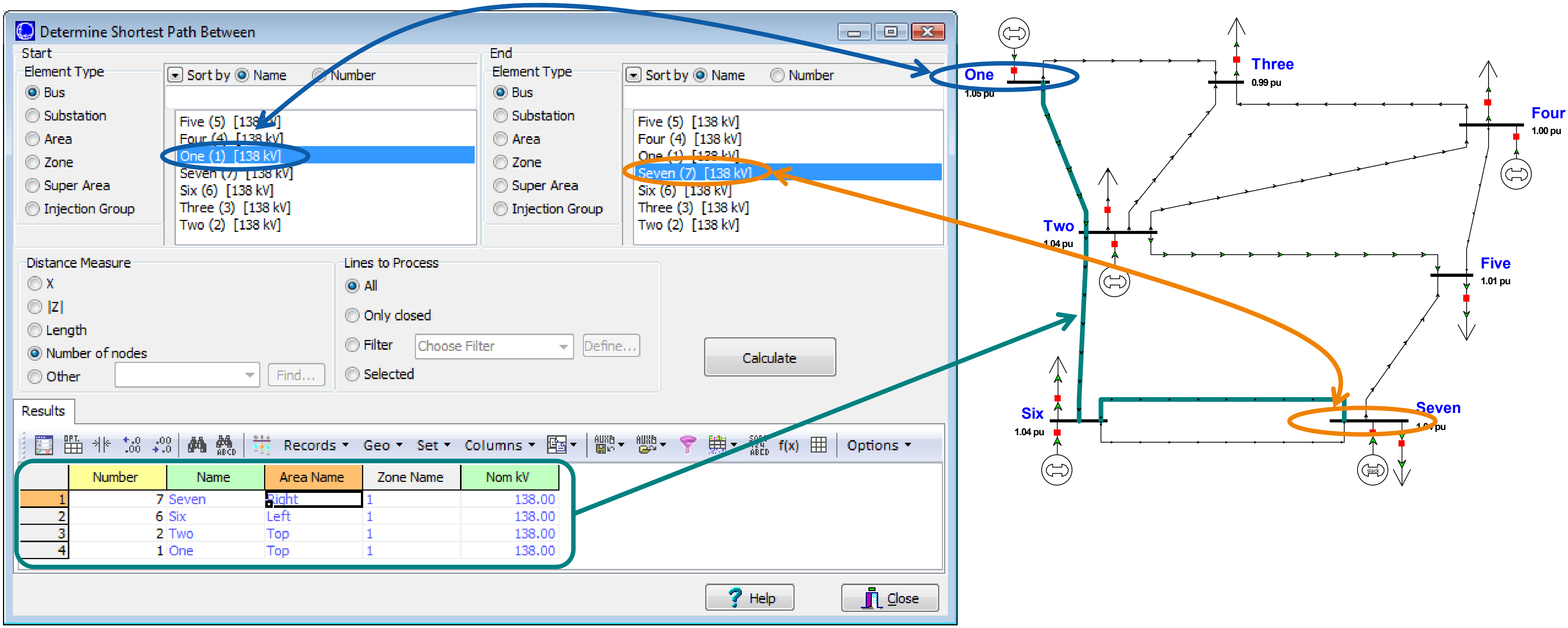
Determine Path Distances From Bus or Group Dialog

- Start Group
  - All buses inside this group will be marked with a distance of zero
- Distance Measure
  - Each branch in the network will be treated as having a distance equal to the choice made here
- Lines to Process
  - Specify a filter to limit the branches that can be traversed during this process
- Bus Field to Populate
  - After clicking **Calculate**, the shortest total distance to the Start Group will be calculated for *EVERY* bus in the system.
  - Result of calculation is pasted into this Bus Field and this bus Field is automatically added to the case information display at the bottom

SCRIPT: DeterminePathDistance([start], BranchDistMeas, BranchFilter, BusField);

Determine Shortest Path

- This tool generates a list of nodes which has the shortest length to connect the “Start” element to the “End” element



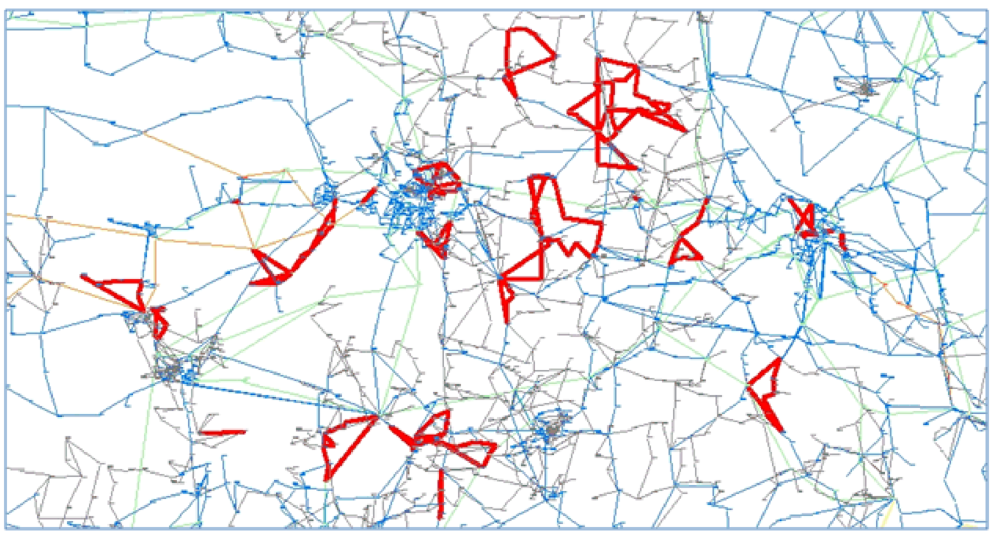
Determine Shortest Path From Bus or Group

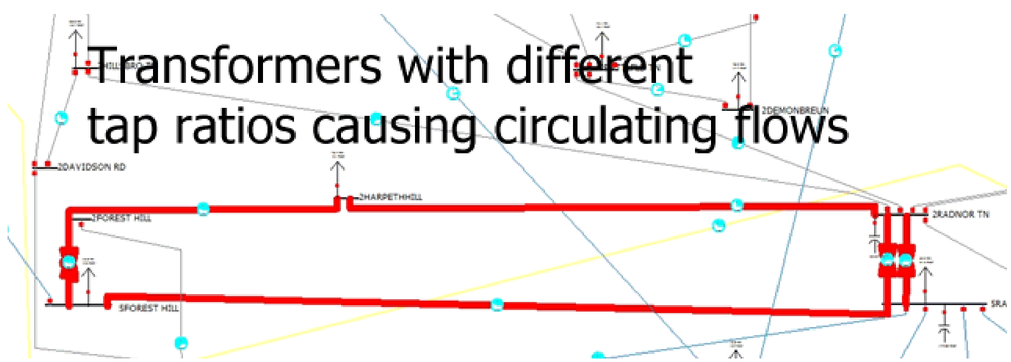
- Start Group, End Group
  - Specify a start and end group to determine distances between
- Distance Measure
  - Each branch in the network will be treated as having a distance equal to the choice made here
- Lines to Process
  - Specify a filter to limit the branches that can be traversed during this process
- Click calculate to determine the shortest series of branches that goes from the Start Group to the End Group.

SCRIPT: DetermineShortestPath([start], [end], BranchDistanceMeasure, BranchFilter, Filename);

Find Circulating MW or MVAr Flows

- Circulating power flows in power systems can lead to unnecessary losses and voltage drops
- Flow cycle- A series of branches with positive flows that can be traversed to form a loop
- Common example- Circulating MVArs caused by transformers with unbalanced tap ratios





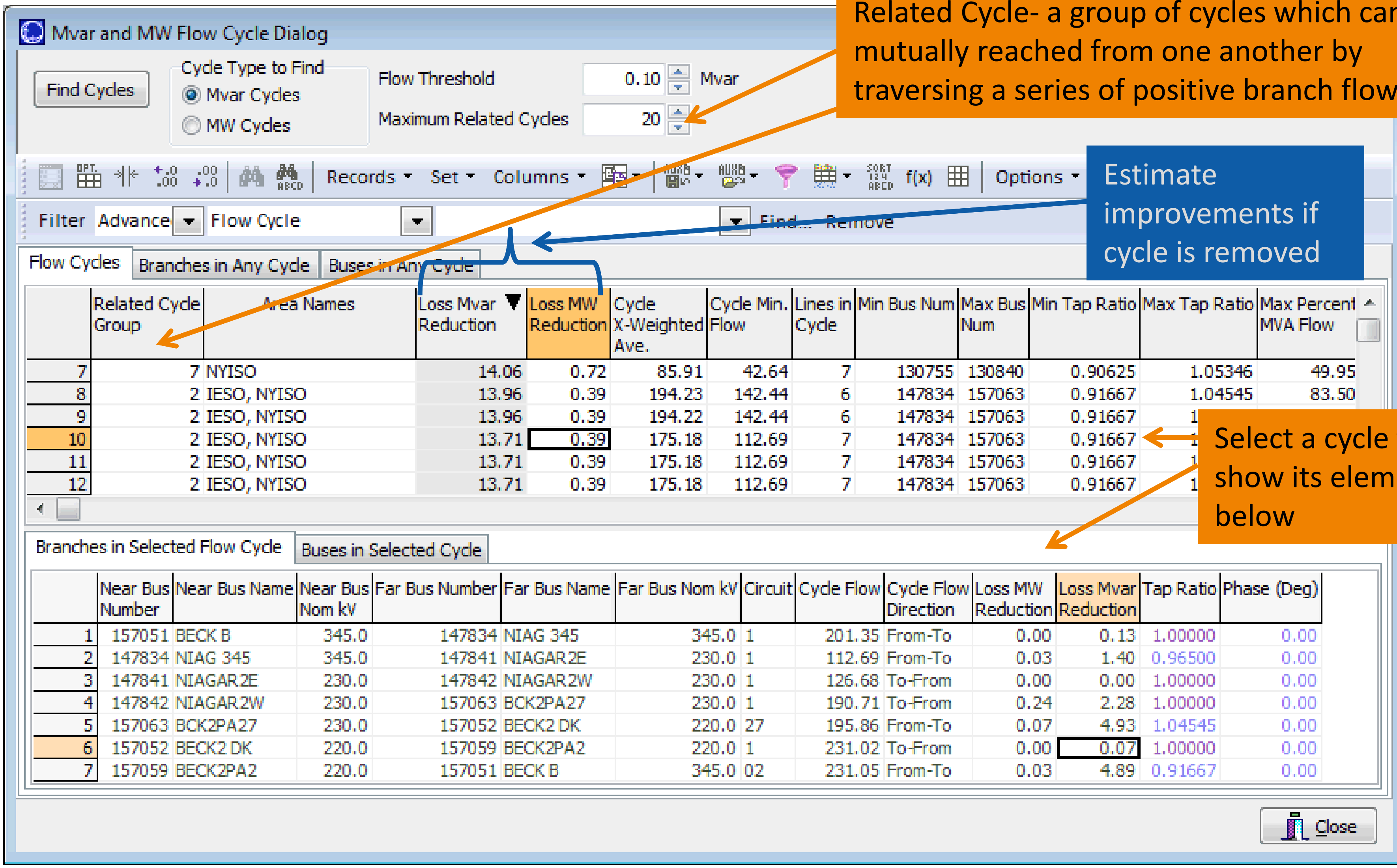
See the PowerWorld help documentation for more details.

Find Circulating MW or MVAr Flows

Related Cycle- a group of cycles which can all be mutually reached from one another by traversing a series of positive branch flows

Estimate improvements if cycle is removed

Select a cycle to show its elements below

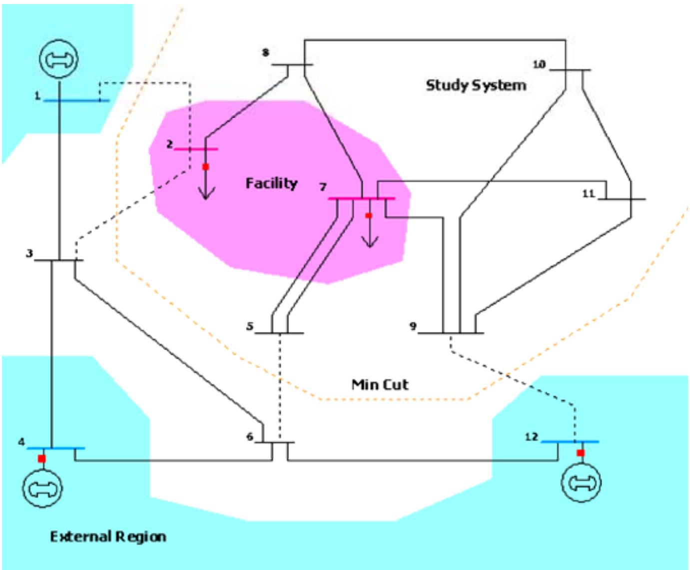


	Related Cycle Group	Area Names	Loss Mvar Reduction	Loss MW Reduction	Cycle X-Weighted Ave.	Cycle Min. Flow	Lines in Cycle	Min Bus Num	Max Bus Num	Min Tap Ratio	Max Tap Ratio	Max Percent MVA Flow
7	7	NYISO	14.06	0.72	85.91	42.64	7	130755	130840	0.90625	1.05346	49.95
8	2	IESO, NYISO	13.96	0.39	194.23	142.44	6	147834	157063	0.91667	1.04545	83.50
9	2	IESO, NYISO	13.96	0.39	194.22	142.44	6	147834	157063	0.91667	1	
10	2	IESO, NYISO	13.71	0.39	175.18	112.69	7	147834	157063	0.91667	1	
11	2	IESO, NYISO	13.71	0.39	175.18	112.69	7	147834	157063	0.91667	1	
12	2	IESO, NYISO	13.71	0.39	175.18	112.69	7	147834	157063	0.91667	1	

	Near Bus Number	Near Bus Name	Near Bus Nom kV	Far Bus Number	Far Bus Name	Far Bus Nom kV	Circuit	Cycle Flow	Cycle Flow Direction	Loss MW Reduction	Loss Mvar Reduction	Tap Ratio	Phase (Deg)
1	157051	BECK B	345.0	147834	NIAG 345	345.0	1	201.35	From-To	0.00	0.13	1.00000	0.00
2	147834	NIAG 345	345.0	147841	NIAGAR2E	230.0	1	112.69	From-To	0.03	1.40	0.96500	0.00
3	147841	NIAGAR2E	230.0	147842	NIAGAR2W	230.0	1	126.68	To-From	0.00	0.00	1.00000	0.00
4	147842	NIAGAR2W	230.0	157063	BCK2PA27	230.0	1	190.71	To-From	0.24	2.28	1.00000	0.00
5	157063	BCK2PA27	230.0	157052	BECK2 DK	220.0	27	195.86	From-To	0.07	4.93	1.04545	0.00
6	157052	BECK2 DK	220.0	157059	BECK2PA2	220.0	1	231.02	To-From	0.00	0.07	1.00000	0.00
7	157059	BECK2PA2	220.0	157051	BECK B	345.0	02	231.05	From-To	0.03	4.89	0.91667	0.00

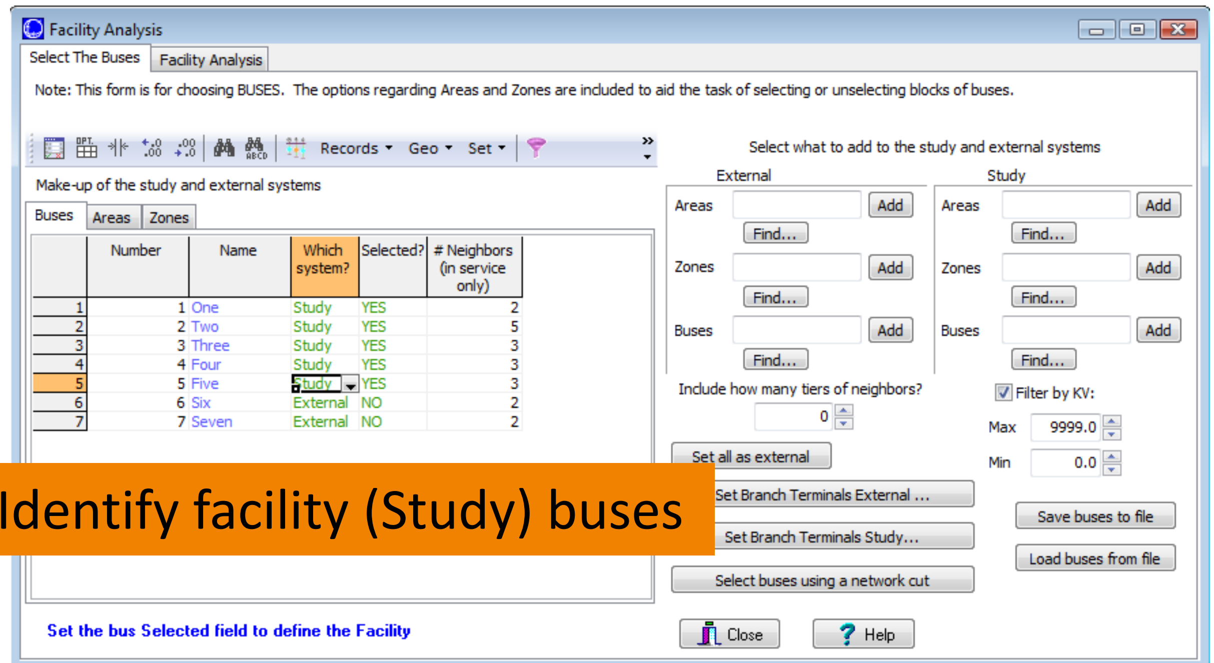
Facility Analysis

- Determine the branches that would isolate the Facility from the External region
- This dialog allows you to choose two sets of buses on the Select the Buses
  - Buses with *Which System?* = EXTERNAL
  - Buses with *Selected?* = YES
- To define the Facility, set *Selected?* = YES and *Which System?* = Study

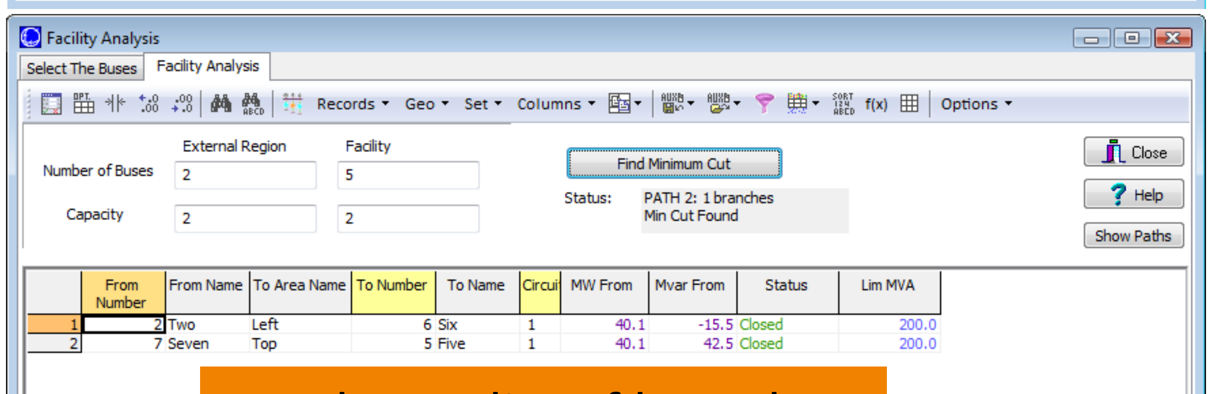


Facility Analysis

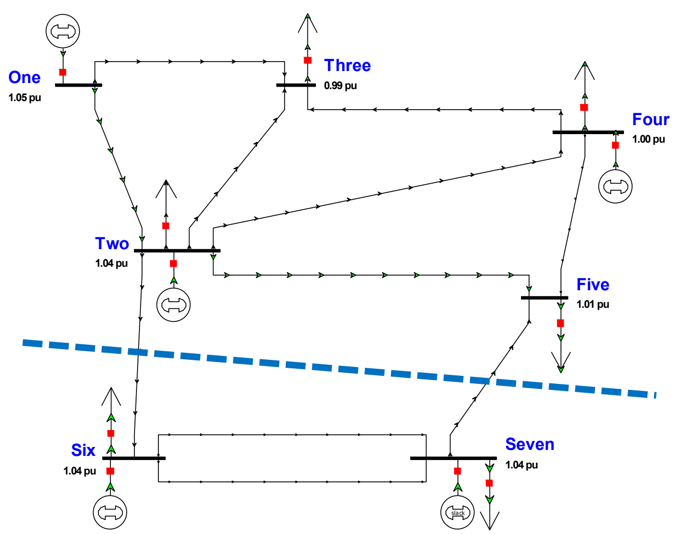
When you then switch to the Facility Analysis Tab, you can click **Find Minimum Cut** to find the minimum number of branches to remove to separate the two sets of buses



Identify facility (Study) buses



Results – a list of branches



Branches that Create Islands

- Find a list of branches that if removed will split the network into two islands.
- Click **Determine Branches** button to execute.
- Lines to Process
  - Specify a filter to limit the branches that will be checked for creating islands
- Middle part of dialog will list the branches that if opened will create an island
- When you choose a branch from the middle list, the bottom portion of the dialog will list the buses that become islanded as a result of the selected branches outage

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