PowerWorld Tutorial

Yen-Yu Lee
The University of Texas at Austin
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Introduction

- PowerWorld is one of the most popular power system simulation tools.
- Evaluation version can be downloaded at: http://www.powerworld.com/download-purchase/demo-software
- Evaluation version can handle up to 12 buses.

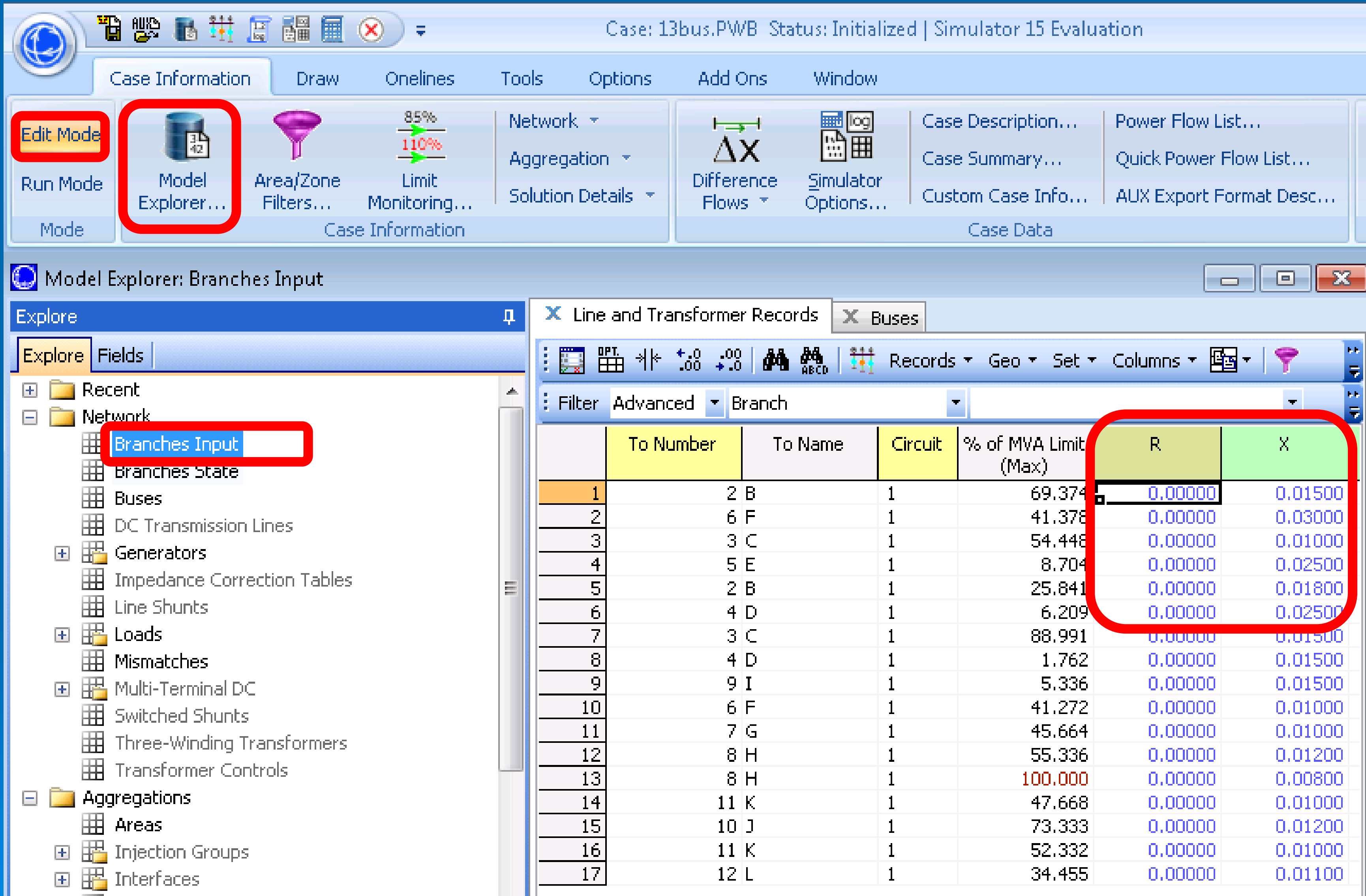
Outline

- In this tutorial, we will cover:
  - Editing a power system model
  - Running power flow
  - Solving optimal power flow (OPF)
  - Showing locational marginal prices (LMP)
  - Extracting Lagrange multipliers from OPF
  - Showing contours of LMP
  - Solving security-constrained OPF
  - Extracting shift factors

Editing a Power System Model

- Open “Model Explorer” under “Case Information”. All system specifications can be edited here.
- For example, to change the line impedance, change the “R” and “X” column under “Branches Input”.
- We can also modify an object by right-clicking it on the one-line diagram.

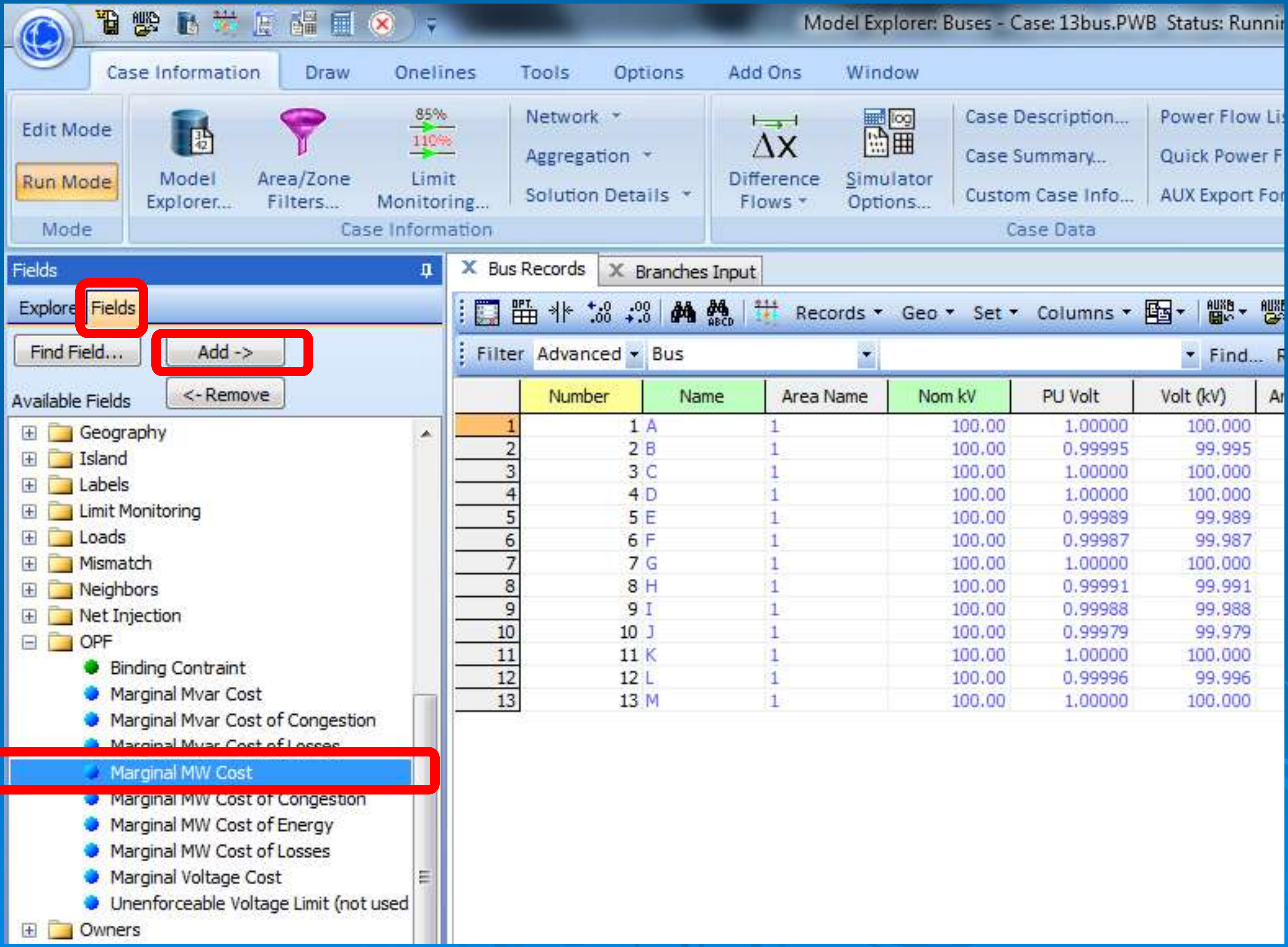
Example: editing line parameters



Example: Adding and Removing Columns

- Not all data is displayed in the table by default.
- To Add/Remove a data column, select "Fields" tab in the Explore Pane.
- Select the data column to add/remove, then click "add->" or "remove <-".
- Note that some columns are editable, some are read-only.

Example: Adding the LMP column

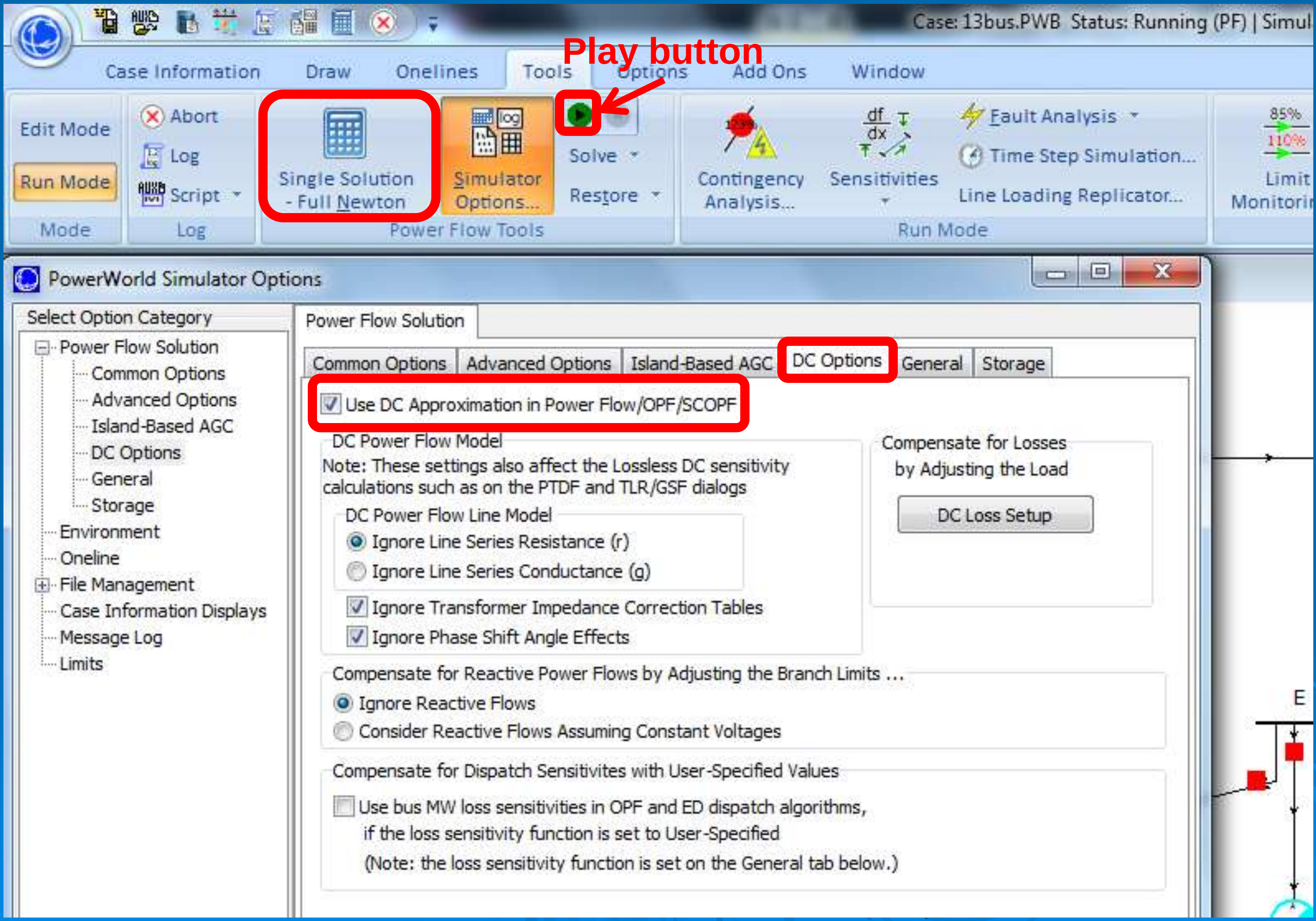


	Number	Name	Area Name	Nom kV	PU Volt	Volt (kV)
1	1	A	1	100.00	1.00000	100.000
2	2	B	1	100.00	0.99995	99.995
3	3	C	1	100.00	1.00000	100.000
4	4	D	1	100.00	1.00000	100.000
5	5	E	1	100.00	0.99989	99.989
6	6	F	1	100.00	0.99987	99.987
7	7	G	1	100.00	1.00000	100.000
8	8	H	1	100.00	0.99991	99.991
9	9	I	1	100.00	0.99988	99.988
10	10	J	1	100.00	0.99979	99.979
11	11	K	1	100.00	1.00000	100.000
12	12	L	1	100.00	0.99996	99.996
13	13	M	1	100.00	1.00000	100.000

Running Power Flow

- To run an AC power flow, simply click the "Single Solution-Full Newton" under "Tools" tab.
- To run DC power flow, click "Simulator Options", and check "Use DC Approximation …" under the "DC options" tab.
- With DC power flow, there should be no reactive power generated.
- Click the "Play" button to show the animation of power flow.

Running power flow

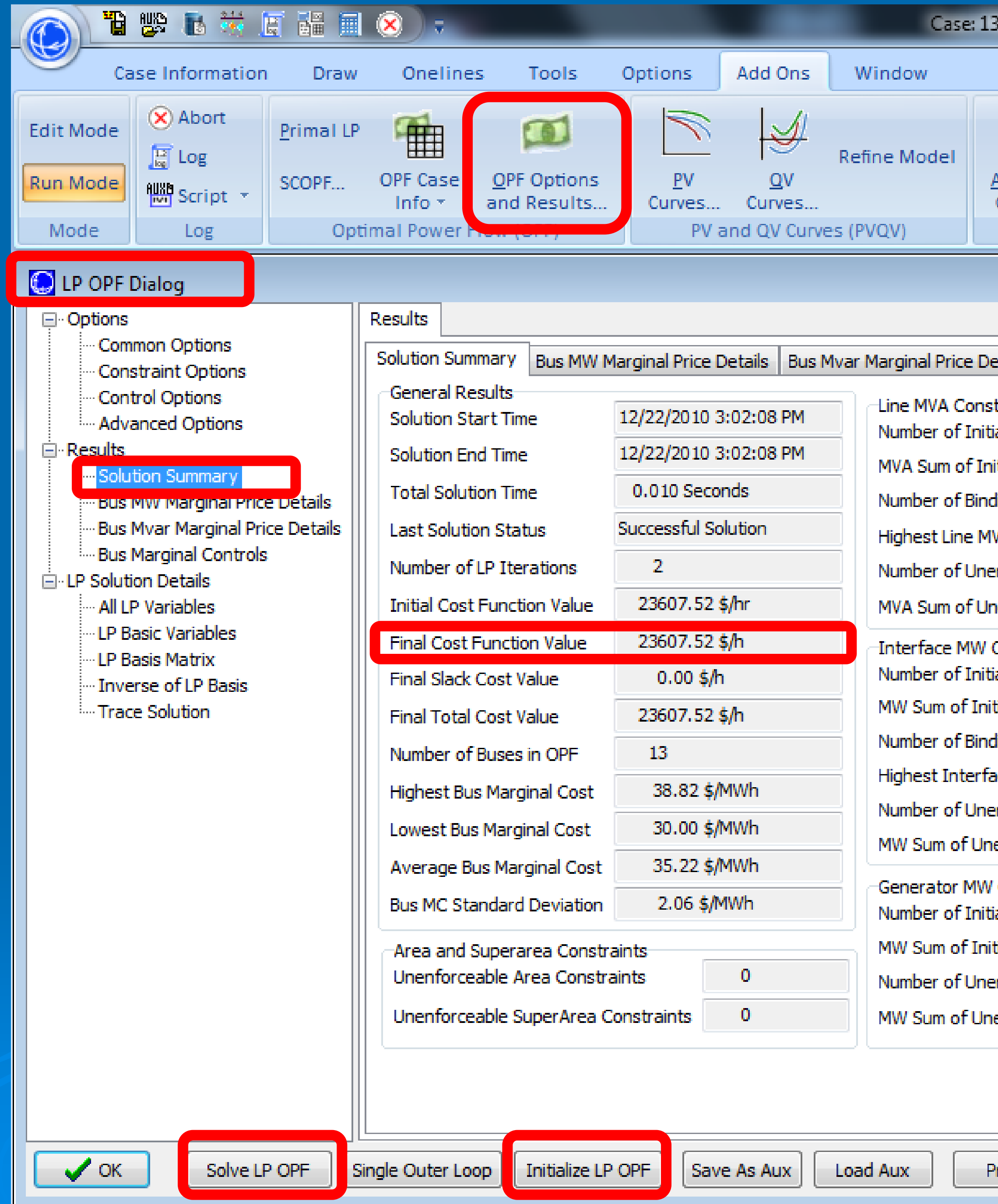


Optimal Power Flow

- Optimal power flow (OPF) determines the least cost dispatch of generators considering transmission constraints.
- If we check the option “Use DC Approximation …” described earlier, DC OPF will be used. Otherwise, AC OPF is used.
- Click “OPF Options and Results …” under “Add Ons” tab to bring up the “LP OPF Dialog”.
- Select “Solution Summary” under “Results”. Then click “Initialize LP OPF”.

Solving OPF

- Click “Solve LP OPF” to run OPF, the total costs is shown in “Final Cost Function Value”.



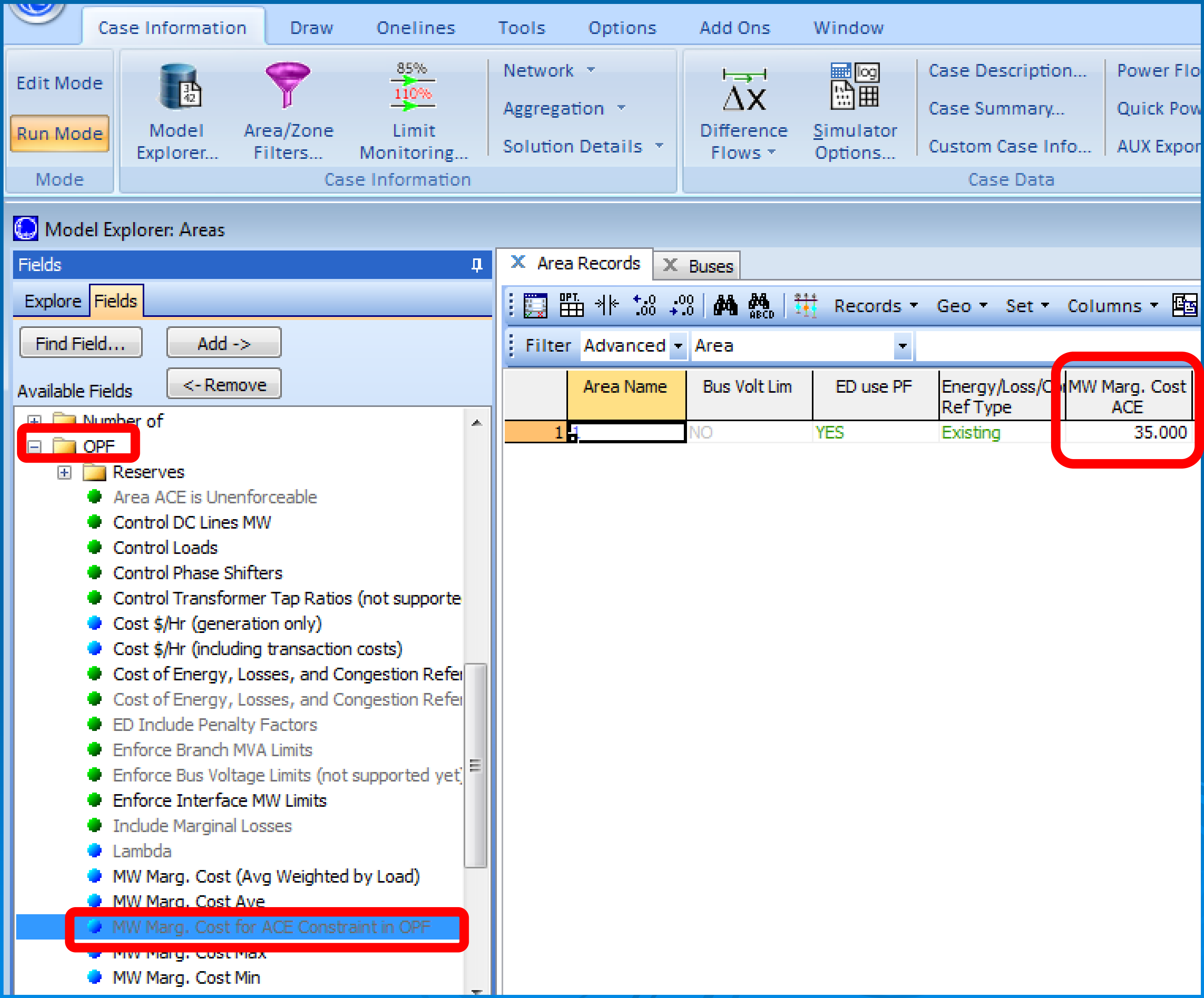
Showing LMP

- Select “Buses” in the “Model Explorer.”
- Add the field “Marginal MW Cost” under “OPF.” (As shown on slide 7.)
- The value indicates the marginal cost of serving one additional unit of demand at a given bus, which is the locational marginal price:
  - See rest of course for details on definition.

Showing Lagrange Multiplier of Power Balance Constraint

- We can show the Lagrange multiplier that represents the “shadow price” of each constraint:
  - See slides on optimization for definitions.
- For the power balance constraint, select “Area” in the “Model Explorer”.
- Add the field “MW Marg. Cost for ACE Constraint in OPF”, which is the Lagrange multiplier of the power balance constraint.

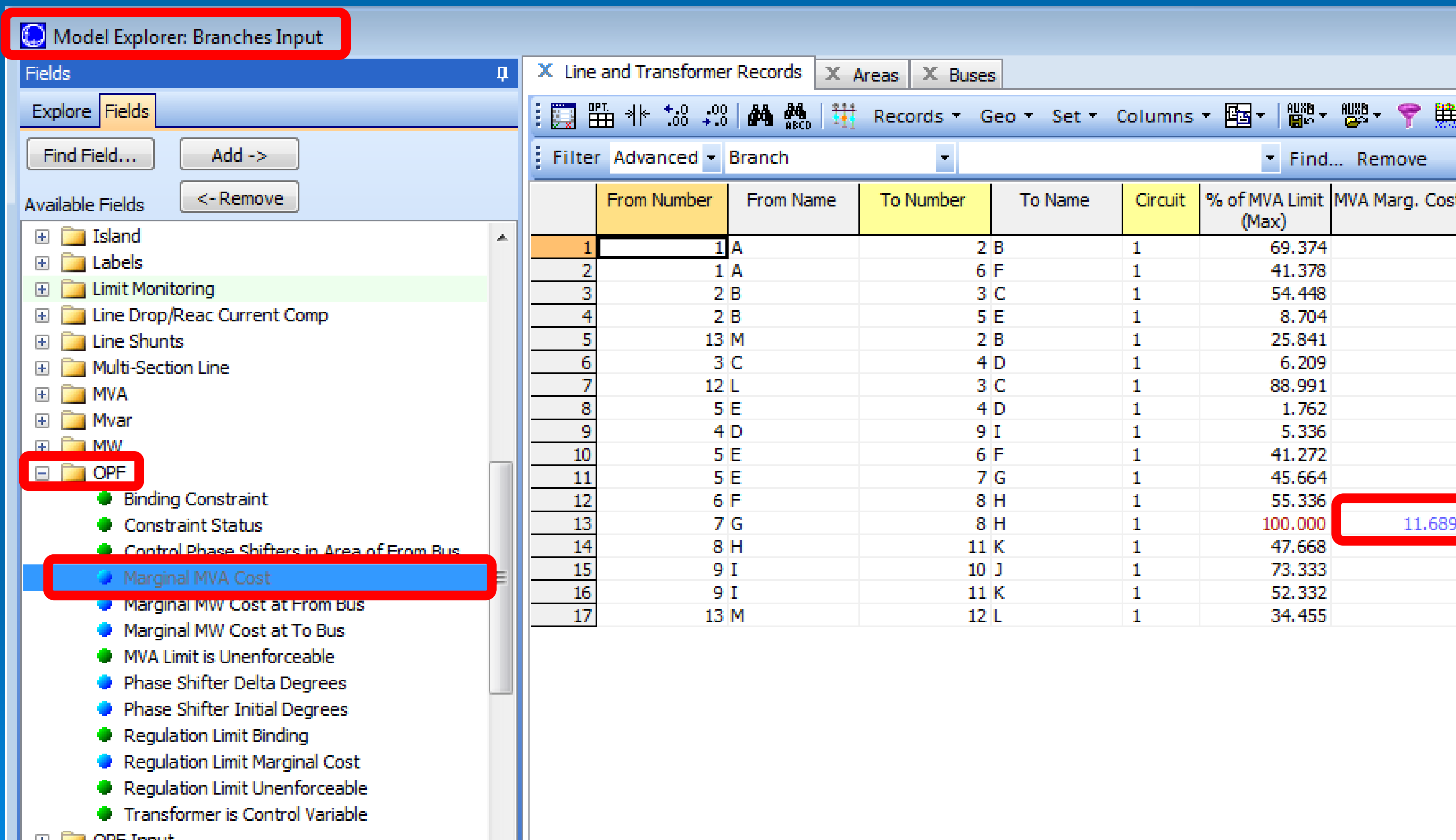
Lagrange Multiplier for Power Balance Constraint



Showing Lagrange Multipliers of Transmission Constraints

- Select the "Branches Input" in the "Model Explorer".
- Add the field "MVA Marg. Cost" under OPF, which is the Lagrange multiplier of the binding transmission constraint.

Lagrange Multipliers for Transmission Constraints

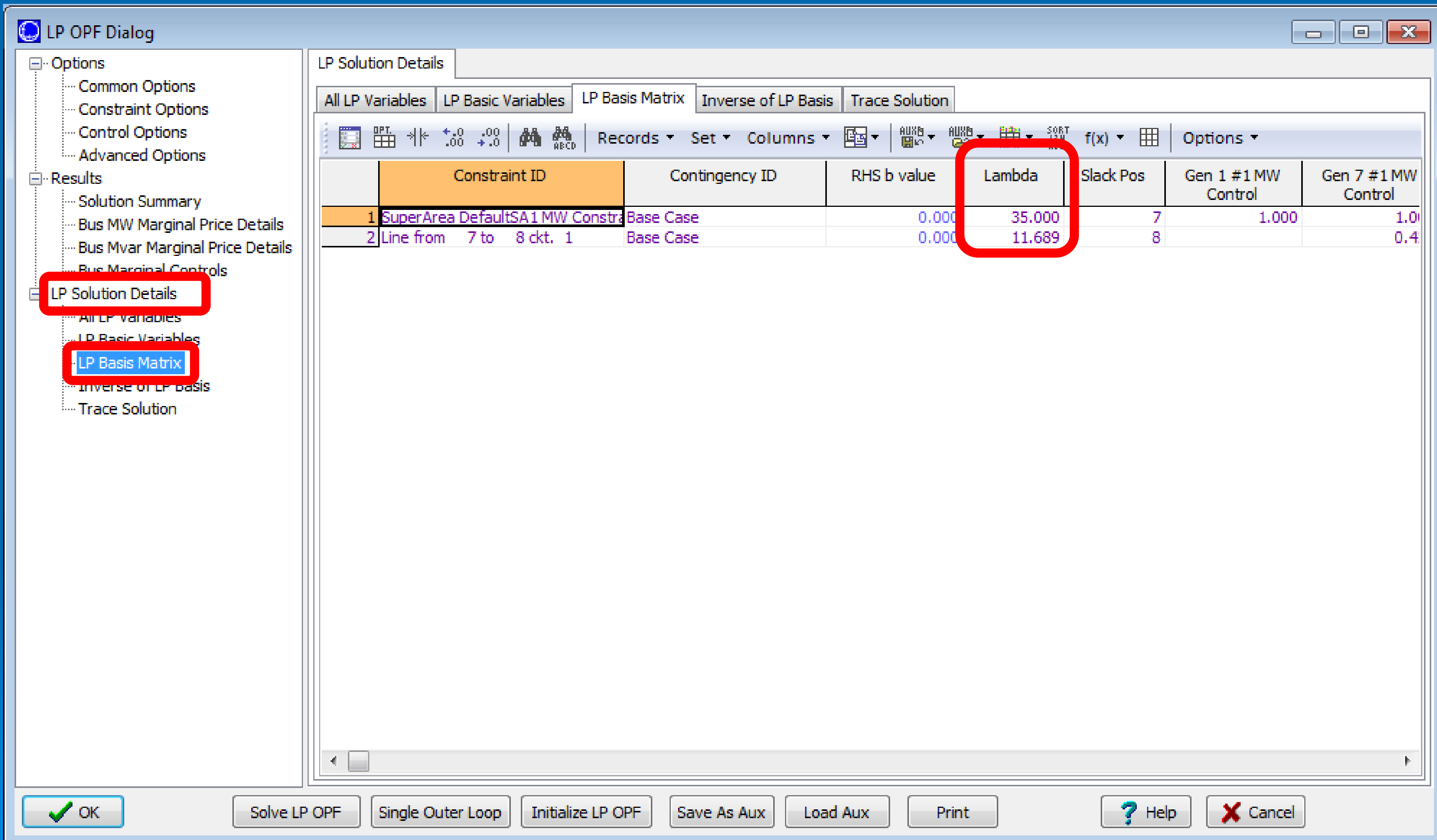


	From Number	From Name	To Number	To Name	Circuit	% of MVA Limit (Max)	MVA Marg. Cost
1	1	A	2	B	1	69.374	
2	1	A	6	F	1	41.378	
3	2	B	3	C	1	54.448	
4	2	B	5	E	1	8.704	
5	13	M	2	B	1	25.841	
6	3	C	4	D	1	6.209	
7	12	L	3	C	1	88.991	
8	5	E	4	D	1	1.762	
9	4	D	9	I	1	5.336	
10	5	E	6	F	1	41.272	
11	5	E	7	G	1	45.664	
12	6	F	8	H	1	55.336	
13	7	G	8	H	1	100.000	11.689
14	8	H	11	K	1	47.668	
15	9	I	10	J	1	73.333	
16	9	I	11	K	1	52.332	
17	13	M	12	L	1	34.455	

Extracting Lagrange Multipliers from LP Solution Details

- Another way to extract Lagrange multipliers.
- Click “OPF Options and Results …” under “Add Ons” tab to call the LP OPF Dialog.
- Select “LP Basis Matrix” under “LP Solution Detail”.
- The data column “Lambda” represents the Lagrange multiplier of each constraint.

Extracting Lagrange Multipliers from LP Solution Details

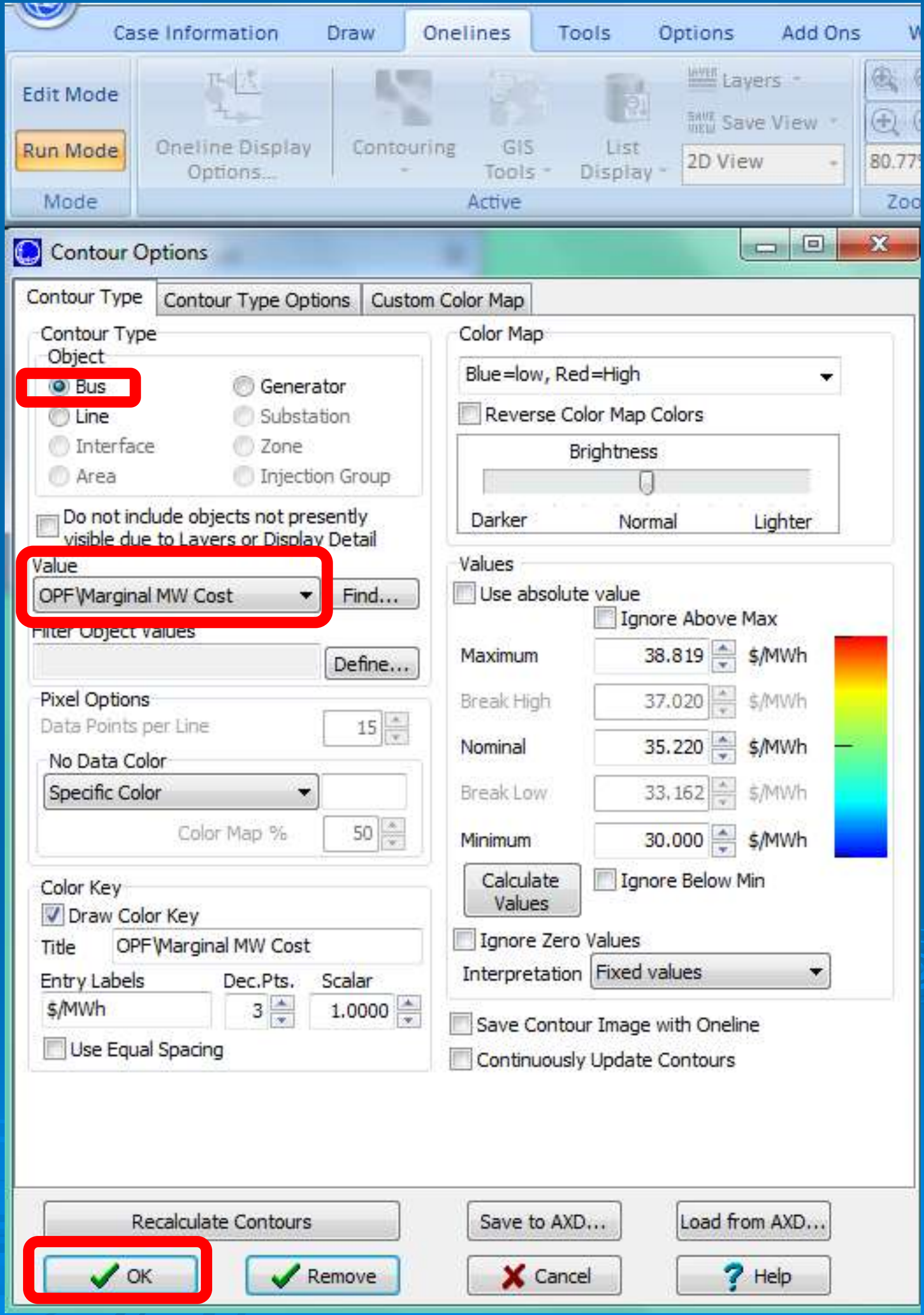


Showing Contours of LMPs

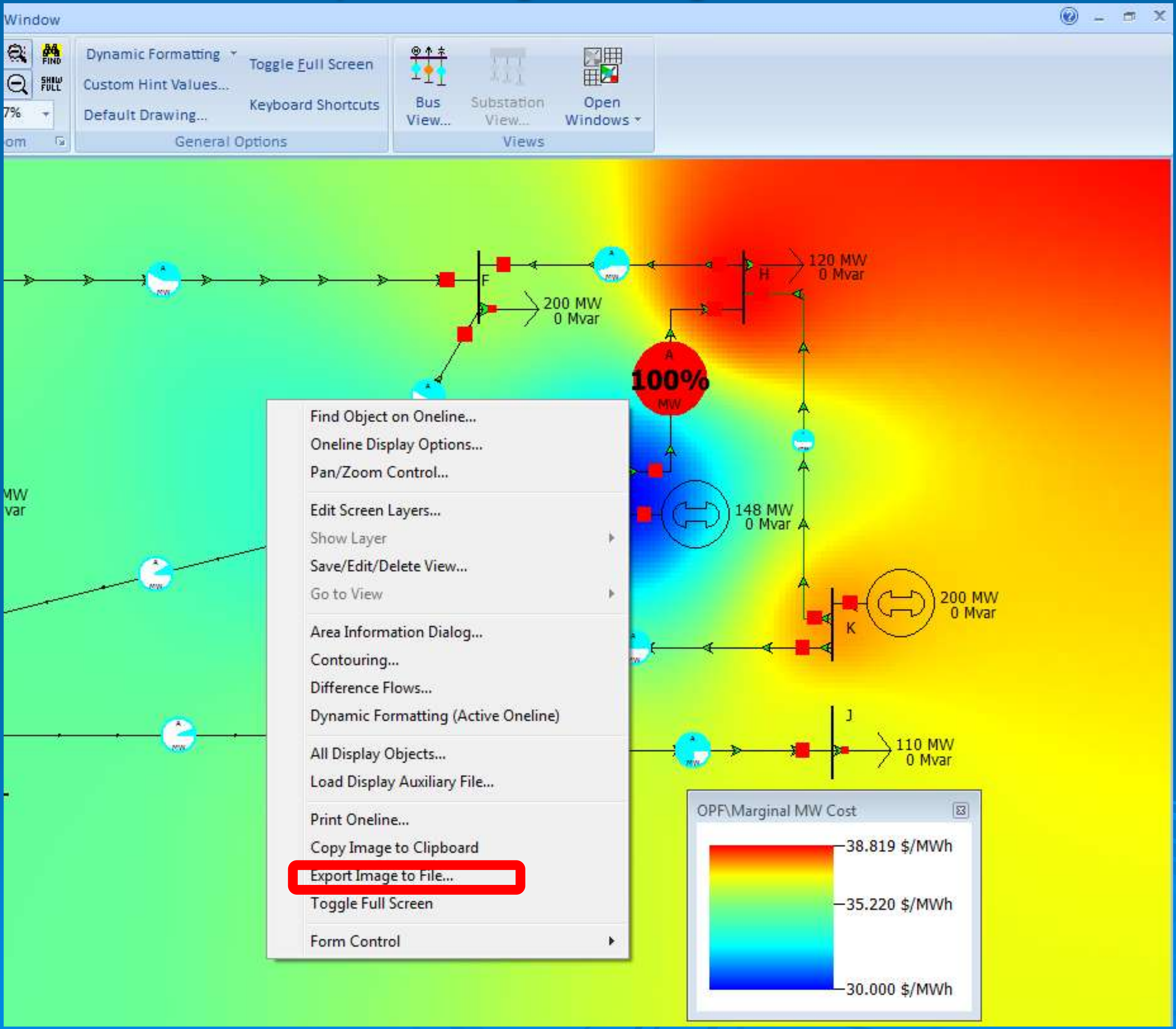
- The “Contouring” function can visualize various numerical data, such as voltages, angles, prices, and etc, as color contours.
- Click “Contouring” in “Onelines” tab.
- Select “Bus” in “Object”, and then select “OPF\Marginal MW Cost” in “Value”.
- Press “OK” to plot contour.

Plotting LMP Contours

- Contour map can be customized by adjustments in “Contour Type Options” and “Custom Color Map”.
- The color contour map can be saved as image file by right-click on the onelines, then choose “Export Image to File”.



Exporting Image to File

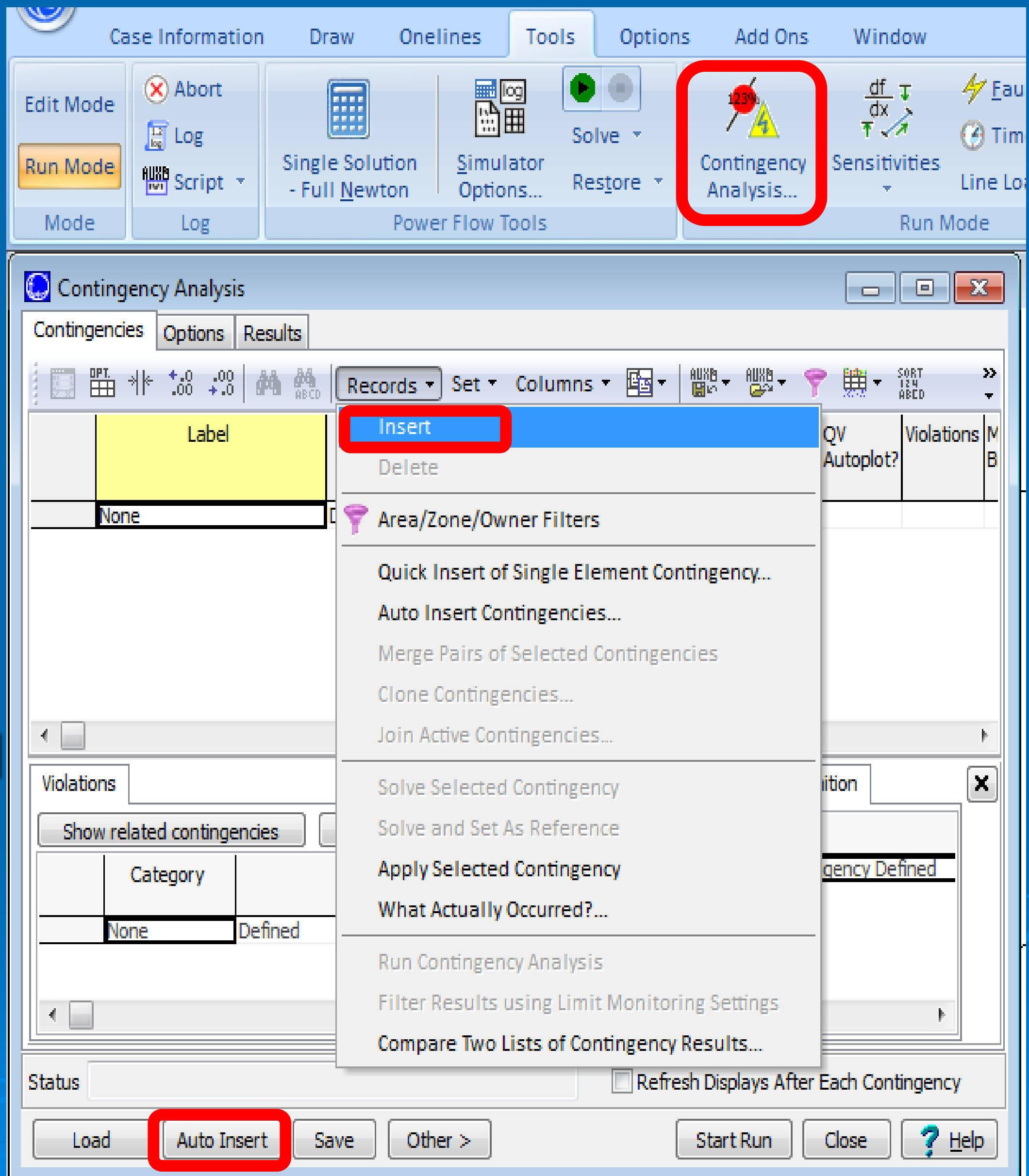


Solving Security-Constrained OPF

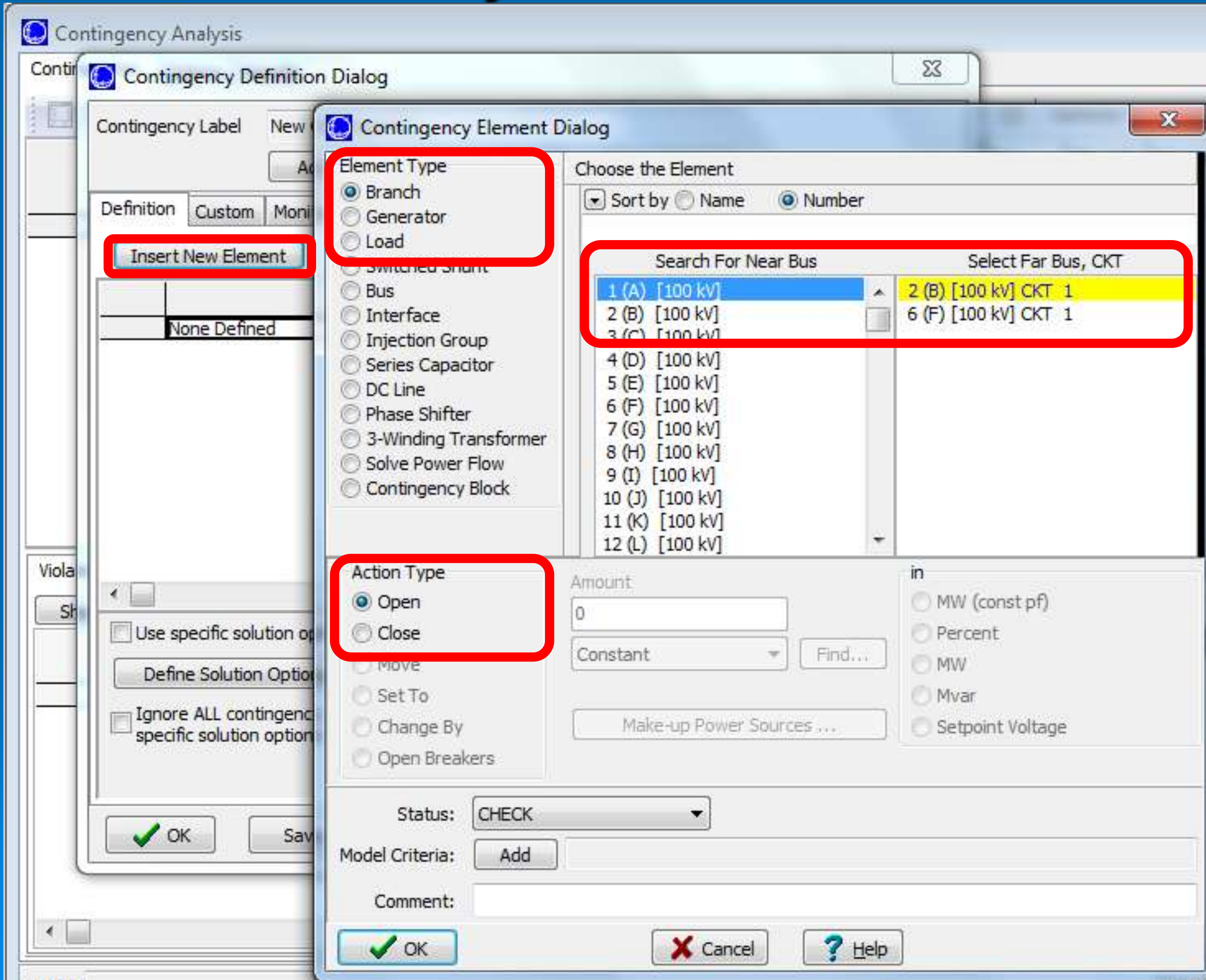
- Security-Constrained OPF (SCOPF) runs iteratively between solving an OPF and running a contingency analysis (CA).
- To solve SCOPF, a contingency list must be defined in advance.
- Select "Contingency Analysis" under "Tools" tab.

Define CA List

- Click “Insert” under “Records”.
- Click “Insert New Element” to bring up the ”Contingency Element Dialog”
- Choose the element and the action type, then press “OK”.
- We could also use Auto Insert to insert multiple contingencies at a time.

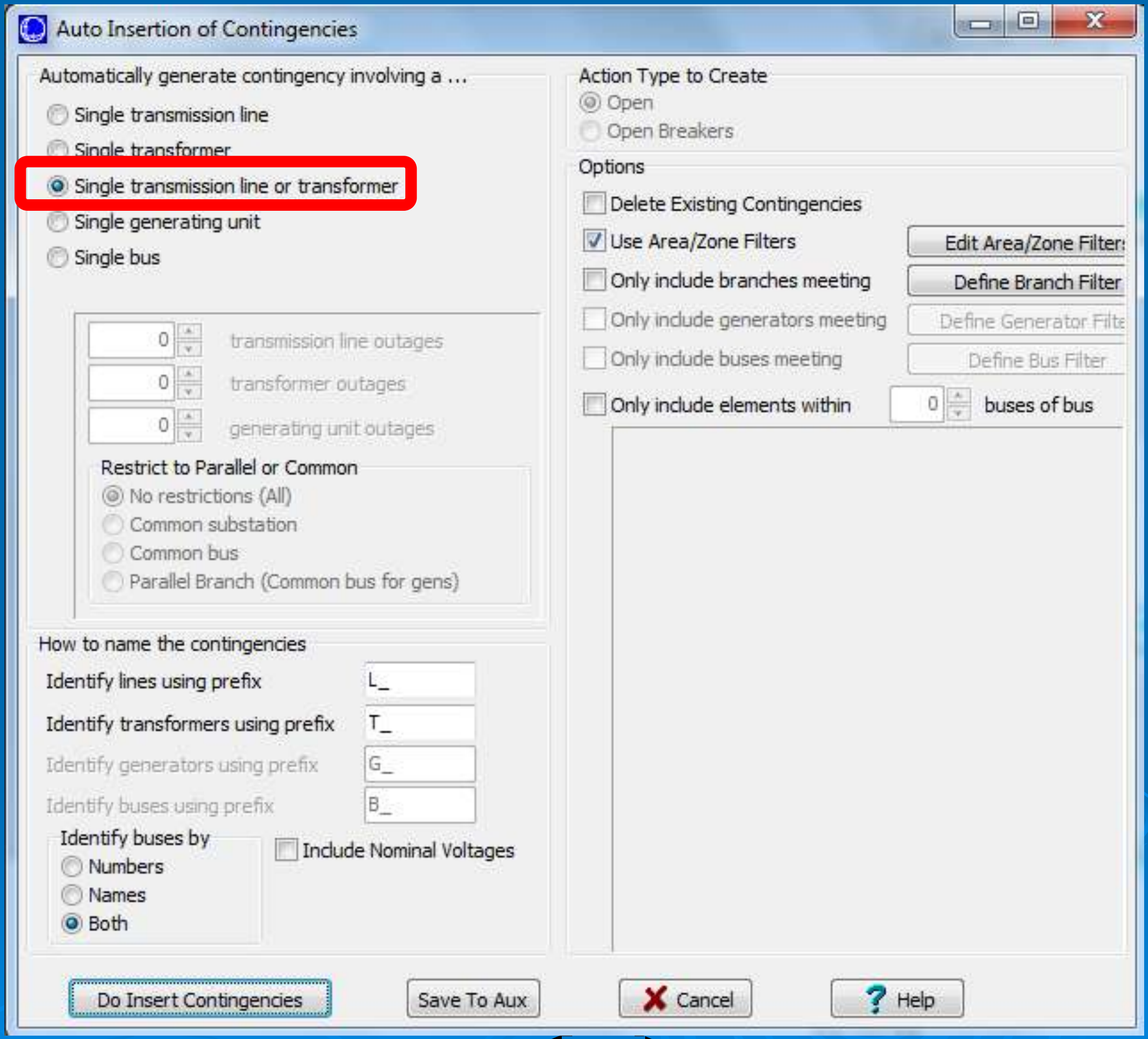


Manually Define CA List



Automatically Define CA List

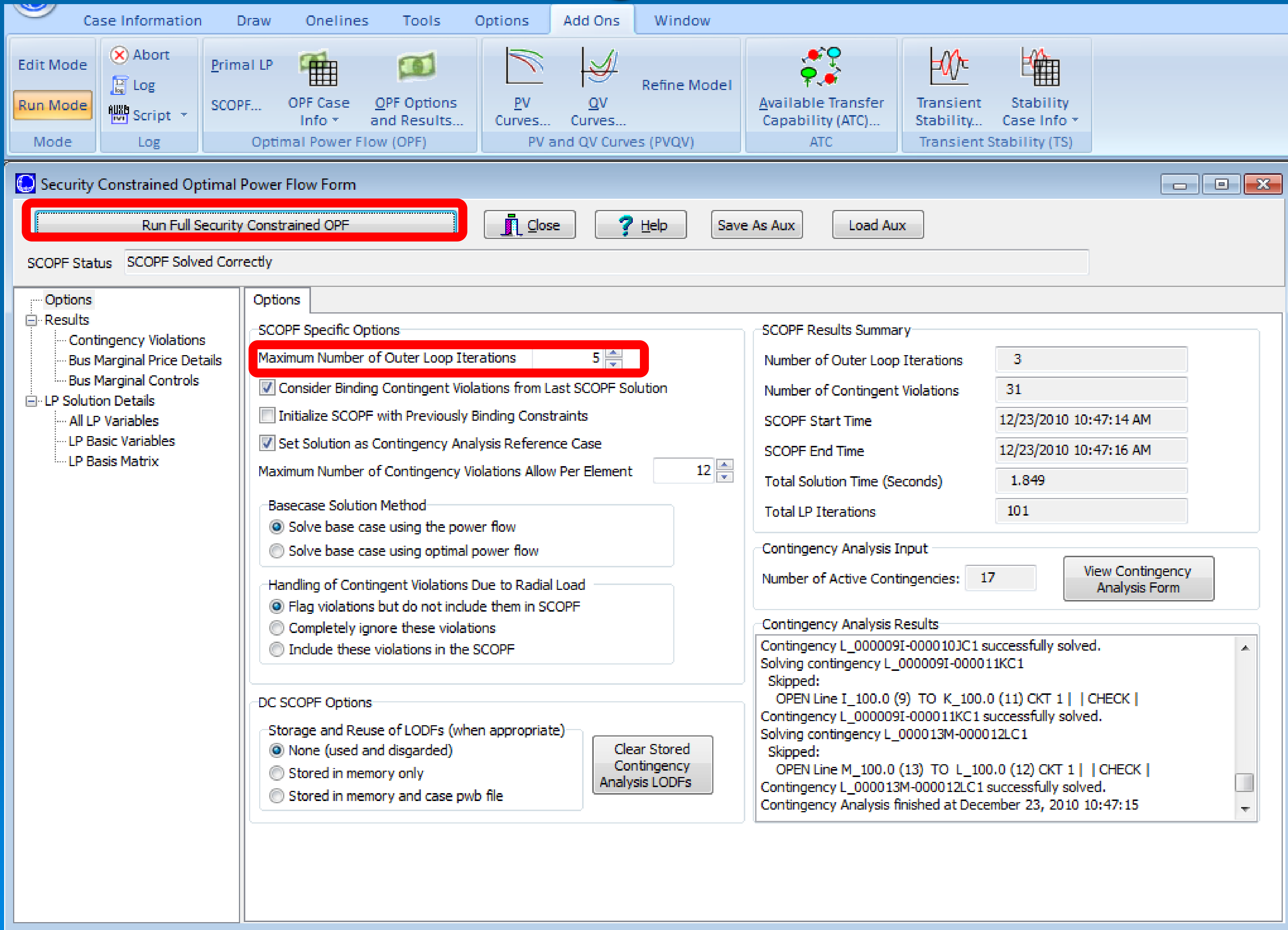
- For example, generating a contingency list with each contingency composed of a single line/ transformer outage.



Solving SCOPF

- Click "SCOPF" under "Add Ons" tab.
- Enter a value in the "Maximum Number of Outer Loop Iterations". For small systems, 10 is usually sufficient.
- Press "Run Full Security Constrained OPF".
- Similar to solving an OPF, we can check the Lagrange Multipliers for both pre- and post-contingency constraints at LP solution details.
- Again, if we check the option "Use DC Approximation …" described earlier, DC SCOPF will be used. Otherwise, AC SCOPF is used.

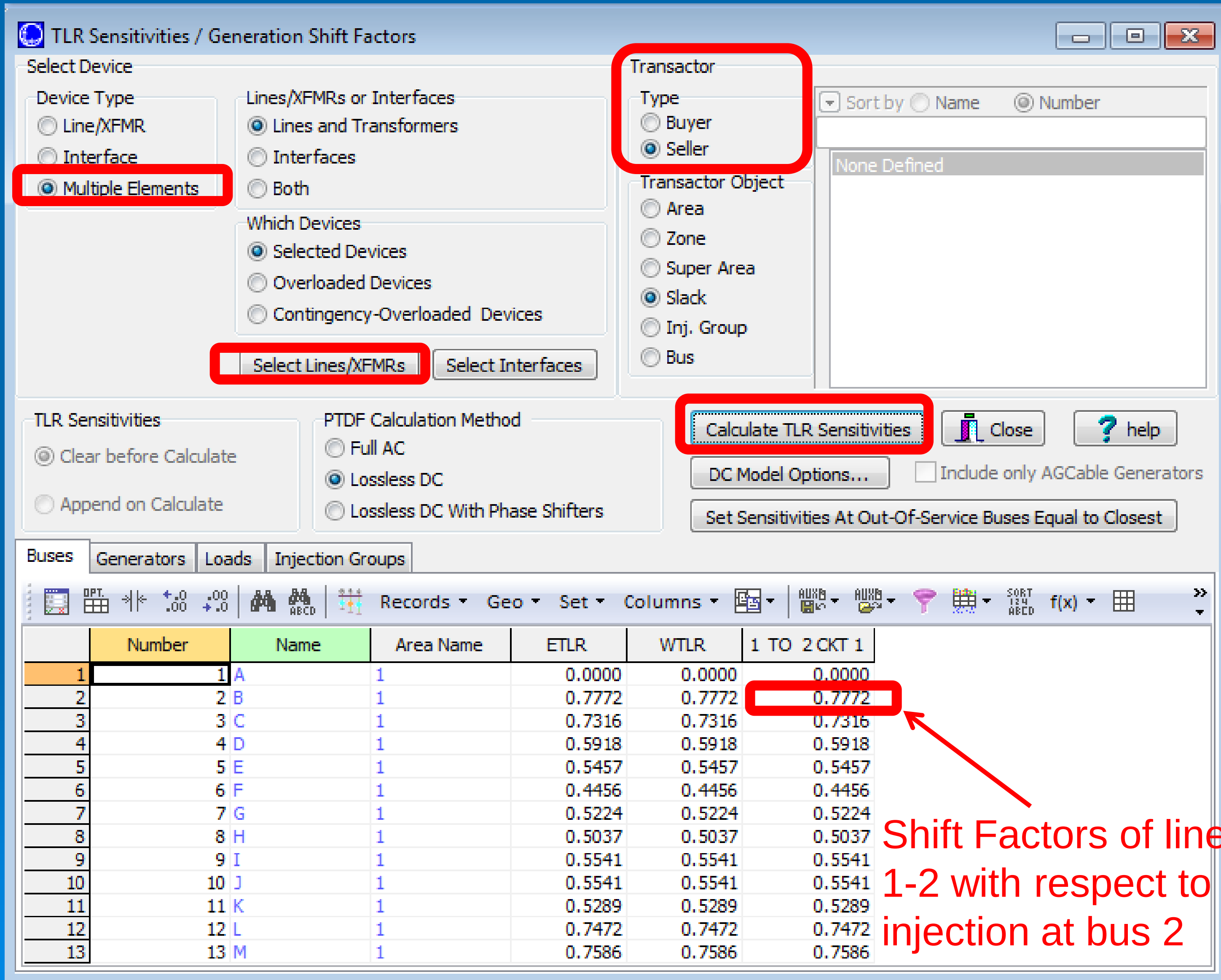
Solving SCOPF



Extracting Shift Factors (Power Transfer Distribution Factors)

- Shift Factors represent the sensitivity of power flow on a given line with respect to power injection at a given bus/zone and withdrawal at another bus/zone.
- Click the "Sensitivities" in "Tools" tab. Select "TLR Sensitivities / Generation Shift Factors".
- Choose "Multiple Element" in "Device Type". Select the line or transformer we are interested in the dialog brought up by clicking "Select Lines/XFMR".
- Transactor type "Seller"/"Buyer" calculates the sensitivities with respect to injecting/withdrawing power.
- Press "Calculate TLR Sensitivities."
- Power transfer distribution factors represent the sensitivity of power flow for injection at a given bus and withdrawal at the slack bus.

Extracting Shift Factors



	Number	Name	Area Name	ETLR	WTLR	1 TO 2 CKT 1
1	1	A	1	0.0000	0.0000	0.0000
2	2	B	1	0.7772	0.7772	0.7772
3	3	C	1	0.7316	0.7316	0.7316
4	4	D	1	0.5918	0.5918	0.5918
5	5	E	1	0.5457	0.5457	0.5457
6	6	F	1	0.4456	0.4456	0.4456
7	7	G	1	0.5224	0.5224	0.5224
8	8	H	1	0.5037	0.5037	0.5037
9	9	I	1	0.5541	0.5541	0.5541
10	10	J	1	0.5541	0.5541	0.5541
11	11	K	1	0.5289	0.5289	0.5289
12	12	L	1	0.7472	0.7472	0.7472
13	13	M	1	0.7586	0.7586	0.7586

Shift Factors of line 1-2 with respect to injection at bus 2

Saving Data into Excel/CSV

- Data shown in a table can be saved into a Excel or csv file.
- Right-click on any table, move cursor on “Copy/Paste/Send”, and select “Send All to Excel”. A Excel spread sheet will be brought up.
- Or, Right-click on the table, move cursor on “Save As”, and select the desired format.

Summary

- Editing a power system model
- Running power flow
- Solving optimal power flow (OPF)
- Showing locational marginal prices (LMP)
- Extracting Lagrange multipliers from OPF
- Showing contours of LMP
- Solving security-constrained OPF
- Extracting shift factors