Using WECC Composite Load Model and PowerWorld Time Step Simulation Tool

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Overview

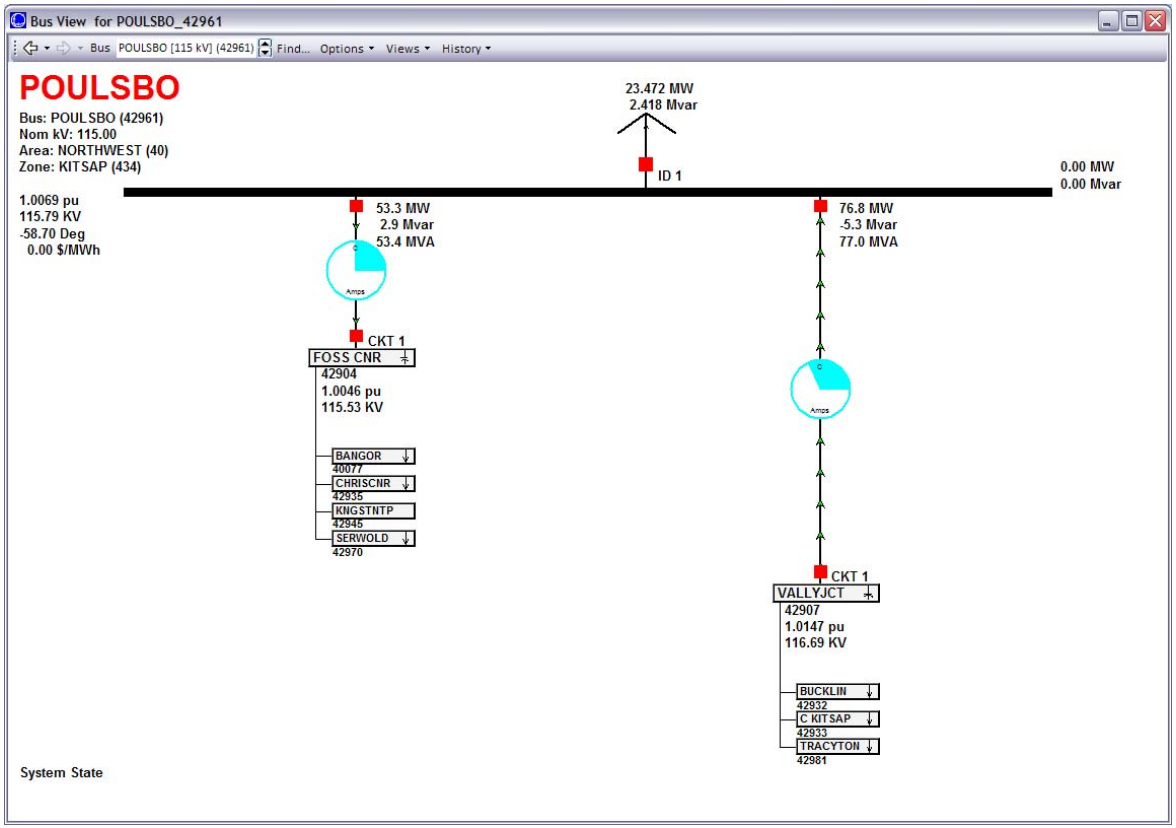
- Introduction to Composite Load Model
- Introduction to Time Step Simulation (TSS)
- Modeling UVLS Relays in PowerWorld
- Running a Time Step Simulation
- Plotting Results
- Identifying Relay Actions

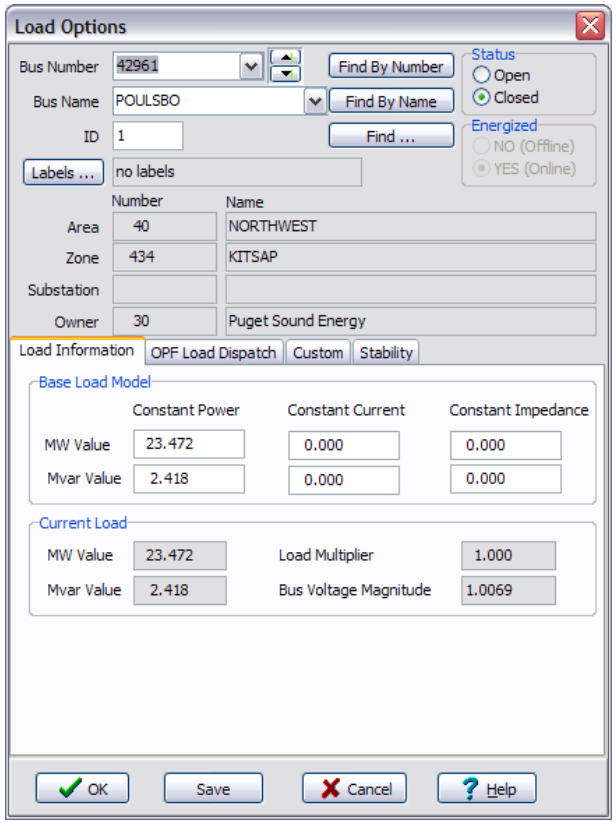
Under Voltage Load Shedding

- Northwest Area utilities completed an evaluation of the existing under voltage load shedding program using TSS
- PowerWorld was utilized for the ability to use the WECC composite load model in powerflow studies
  - The WECC Composite Load Model (CMPLDW) was used to more accurately capture voltage sensitive load behavior post-contingency
  - This allows study of post-transient timeframe (30 seconds to several minutes)
- Is UVLS Program still necessary and are relays properly coordinated?

WECC Composite Load Model

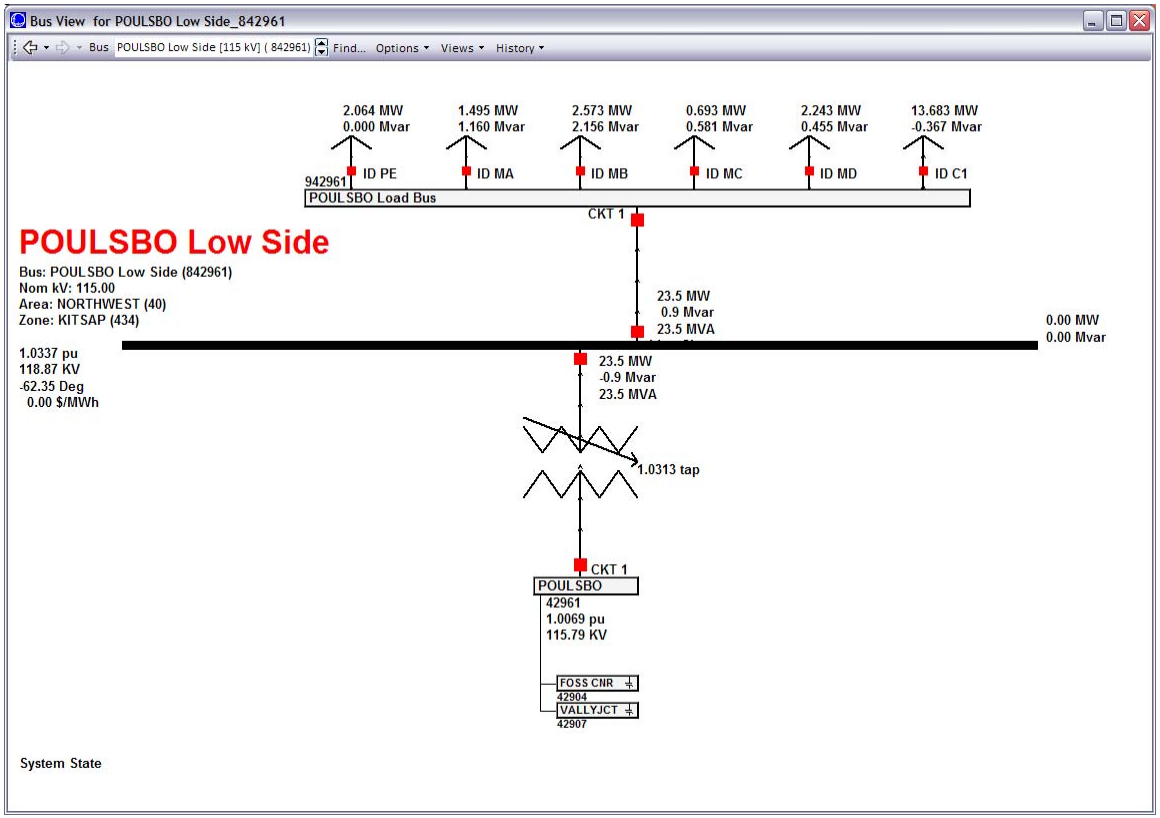
- Powerflow cases typically model loads as constant power
  - Distribution transformer and feeder impedance are included with the load.

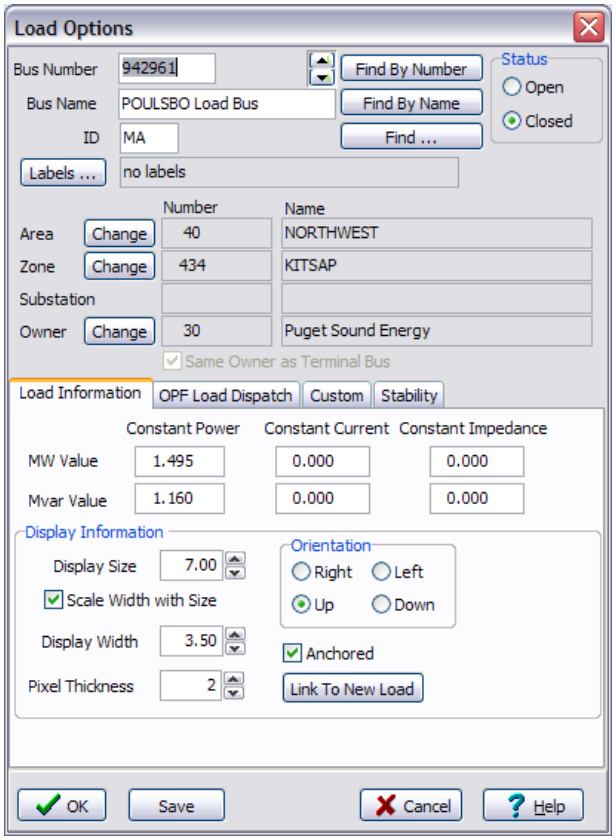




WECC Composite Load Model

- Composite Load Model explicitly models distribution transformer and feeder characteristics, as well as the characteristics of individual load components





WECC Composite Load Model

- **Motor A load (MA)**: three-phase motor with constant torque representative of compressor motors found in commercial air-conditioners and refrigerators
- **Motor B load (MB)**: high inertia motors with speed-dependent load representative of motors driving pumps
- **Motor C load (MC)**: low inertia motors with speed-dependent load also representative of motors driving pumps
- **Motor D load (MD)**: single-phase residential air-conditioners and heat pumps
- **Power electronic load (PE)**: computers and loads with variable frequency drives
- **Static load (C1)**: incandescent lights and resistive space and water heating.

WECC Composite Load Model

- Composite Load Model was originally designed for use in transient stability simulations
  - PowerWorld developed a feature to explore mid-term dynamics of the distribution voltage regulator data in the model
- Motor and electronic loads in the powerflow conversion are constant MVA
  - The user can optionally change these to voltage sensitive static load (ZIP) quantities, if data is available

Conversion to ZIP

- James Randall at Bonneville Power Administration (BPA) developed the coefficients for the various load types to convert loads to an equivalent ZIP Model
- Gordon Comegys at ColumbiaGrid automated many of the processes used in this study for converting loads and correctly modeling generation and reactive resources

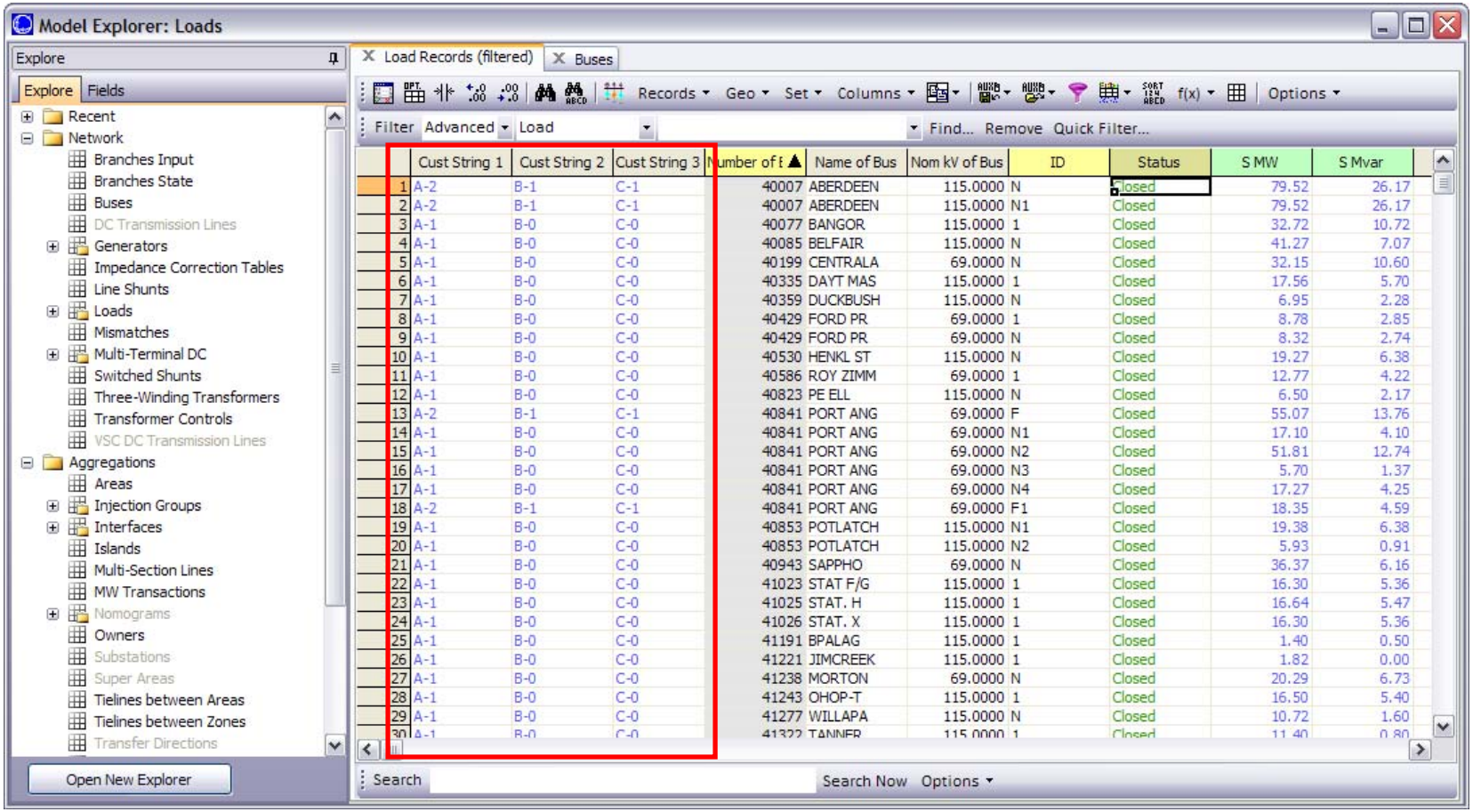
Conversion to ZIP

- Converting loads to a ZIP model requires load types to be identified based on their composite load model parameters.
- Coefficients are then applied according to load type

	Curve Fit Values for ZIP Loads in Powerflow for V > 0.70 pu							Inputted Model Parameters in transient stability					
3-ph models													
Type	**P2**	**P1**	**P0**	**Q2**	**Q1**	**Q0**		**LFm**	**Rs**	**Ls**	**Lp**	**Lpp**	**Tpo**
A-0	2.30904487	-4.95449465	12.66104843	12.44320991	-11.62314620	6.90654157		0.75	0.04	1.8	0.1	0.083	0.092
A-1	2.46455413	-5.28198435	12.83490537	13.82886316	-14.73577004	8.79743601		0.75	0.04	1.8	0.12	0.104	0.095
A-2	0.76768404	-1.74991097	10.99133616	19.65320030	-35.42313108	21.31180638		0.85	0.01	3.1	0.2	0.165	0.8
B-0	-1.14336406	2.81550470	8.27497622	16.11702461	-20.41284136	12.90391326		0.75	0.03	1.8	0.19	0.14	0.2
B-1	-0.94473973	2.10515417	8.81819407	16.65445734	-29.34788005	18.23158032		0.85	0.01	3.1	0.2	0.165	0.8
C-0	-1.01262198	2.53447426	8.42663730	16.23281081	-20.65021157	13.02638552		0.75	0.03	1.8	0.19	0.14	0.2
C-1	-0.80067797	1.80034658	8.98158312	16.85220855	-29.74388969	18.43100320		0.85	0.01	3.1	0.2	0.165	0.8
default	-2.76112462	6.47423901	6.20249684	14.98782521	-20.77827999	13.59243804		0.8	0.02	2	0.2	0.2	0.16
1-ph AC Motor Load													
Type	**P2**	**P1**	**P0**	**Q2**	**Q1**	**Q0**		**LFmd**	**Rsd_CompPFd**	**Lsd_Vstalld**	**Lpd_Rstalld**	**Lppd_Xstalld**	**Tpod_Tstalld**
D-0	0.00000000	0.00000000	10.00000000	54.09355891	-91.69999357	39.66742059		1	0.98	0.54	0.1	0.1	0.03

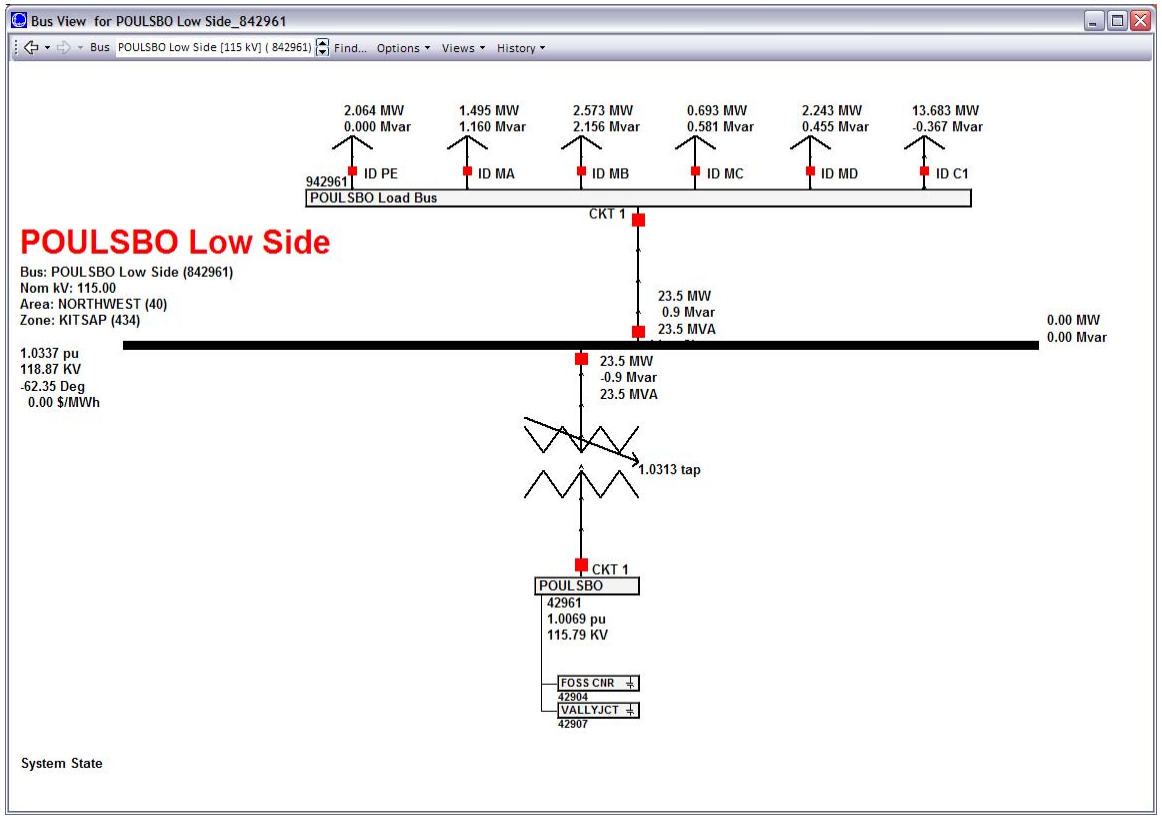
Conversion to ZIP

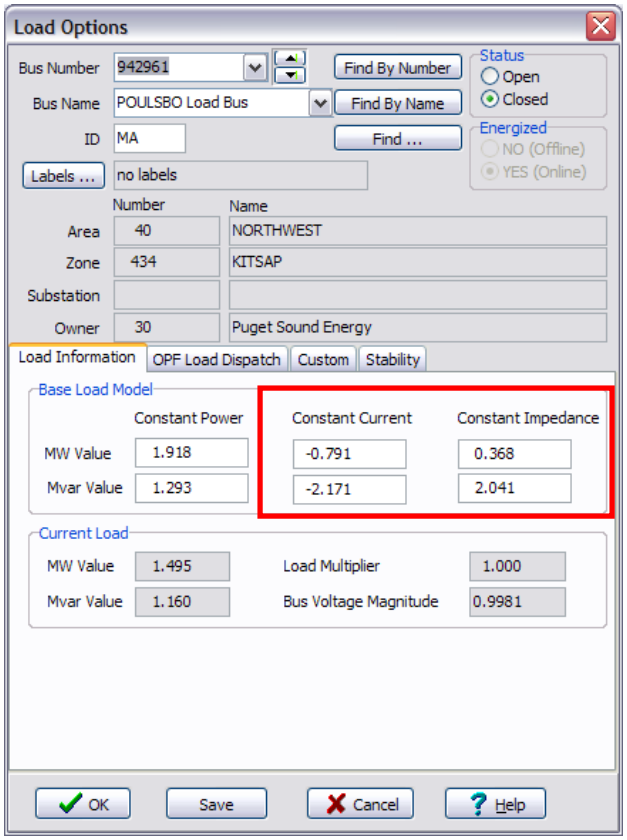
- The ZIP conversion process can be automated with an .aux file once custom strings are populated in the case



Conversion to ZIP

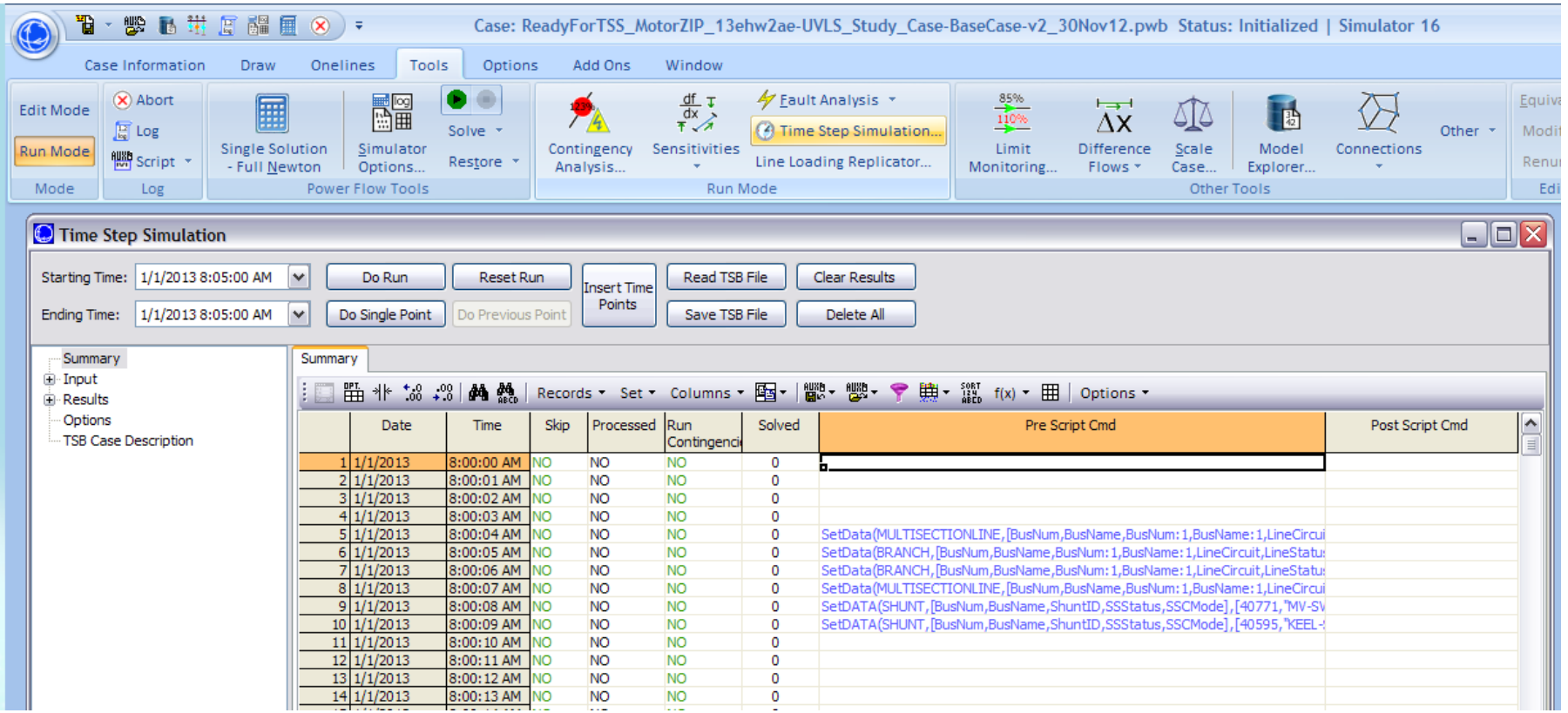
- Composite Load Model with ZIP Equivalent
  - Constant Current and Constant Impedance load components are now populated





Time Step Simulation Tool - Overview

- Time Step Simulation Tool is located under the Tools tab in Simulator
- Allows the user to specify operating conditions and obtain power flow solutions for a set of points in time.

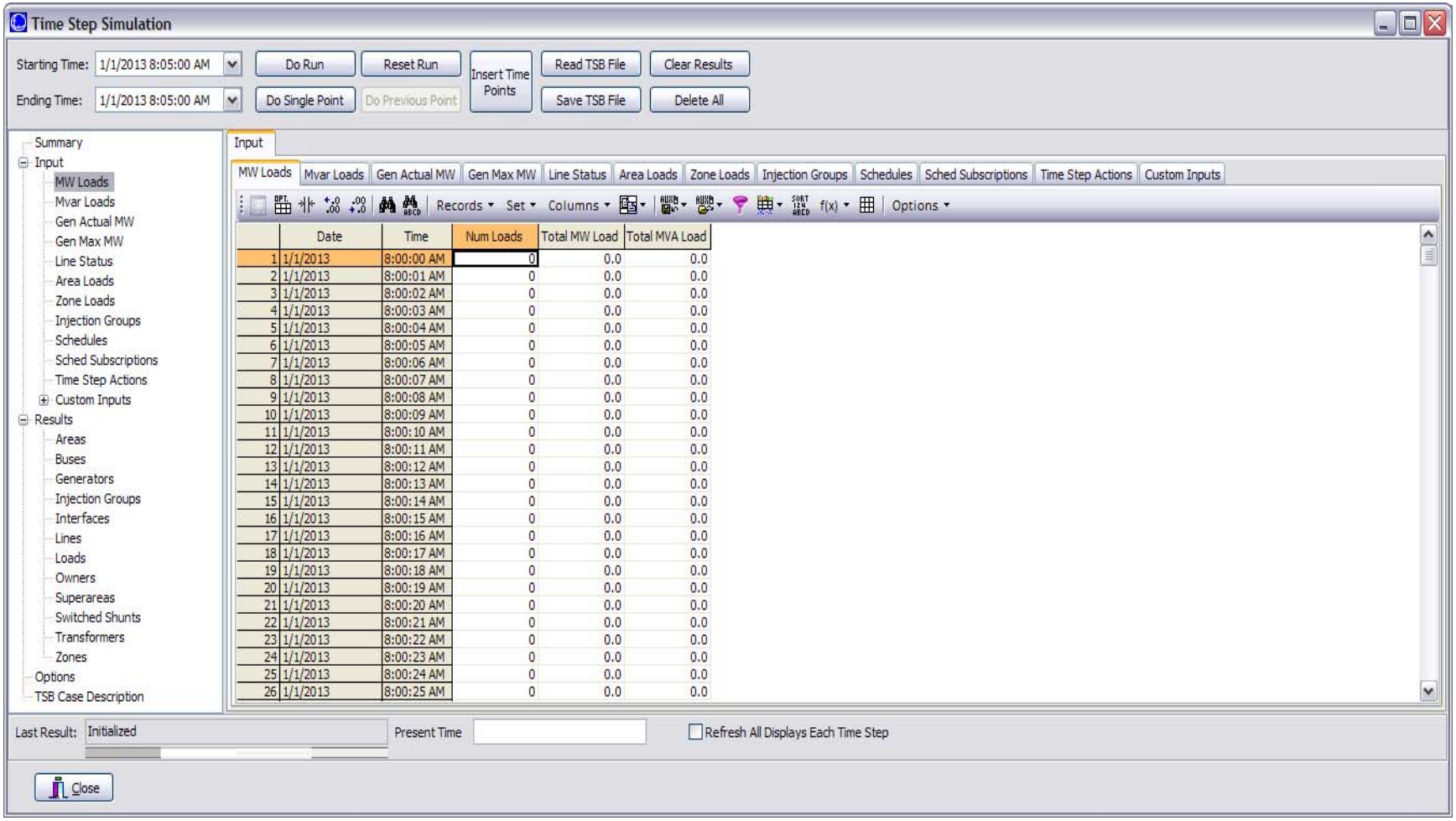


Time Step Simulation Tool - Overview

- Pre-powerflow and post-powerflow actions are specified in the form of Script Commands
- These Script Commands can consist of individual actions
  - Example: Using the SetData command
    SetData(BRANCH,[BusNum,BusName,BusNum:1,BusName:1,LineCircuit,LineStatus])
  - SetData can be used to change the status of any power system element as well as to set Simulator Solution Options
- Groups of actions can be scripted in an .aux file and loaded using the LoadAux command
  - LoadAux(“FileLocation.aux”,”Yes”)

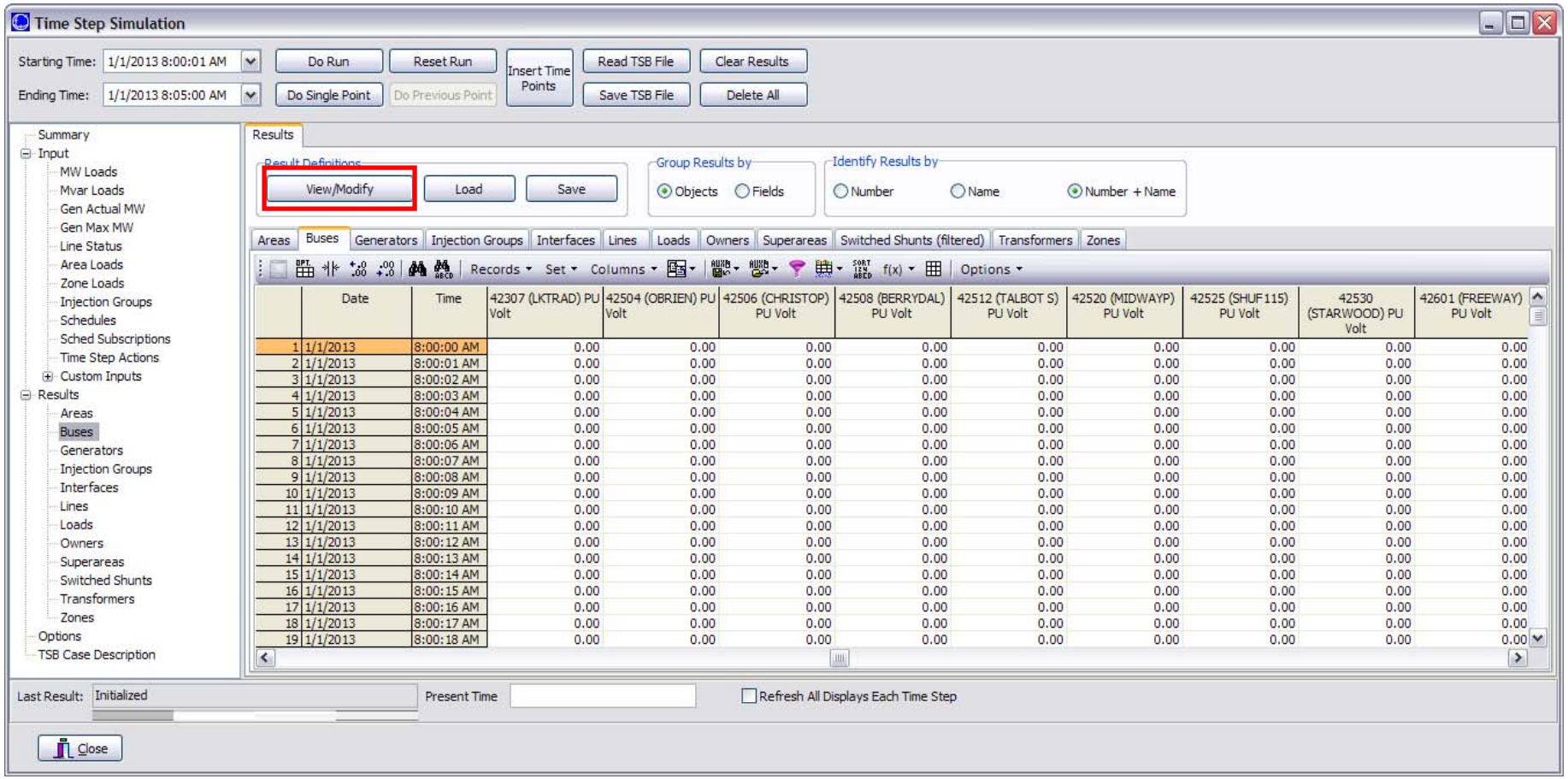
Time Step Simulation Tool - Overview

- The input tab allows data to be input on a time point basis.



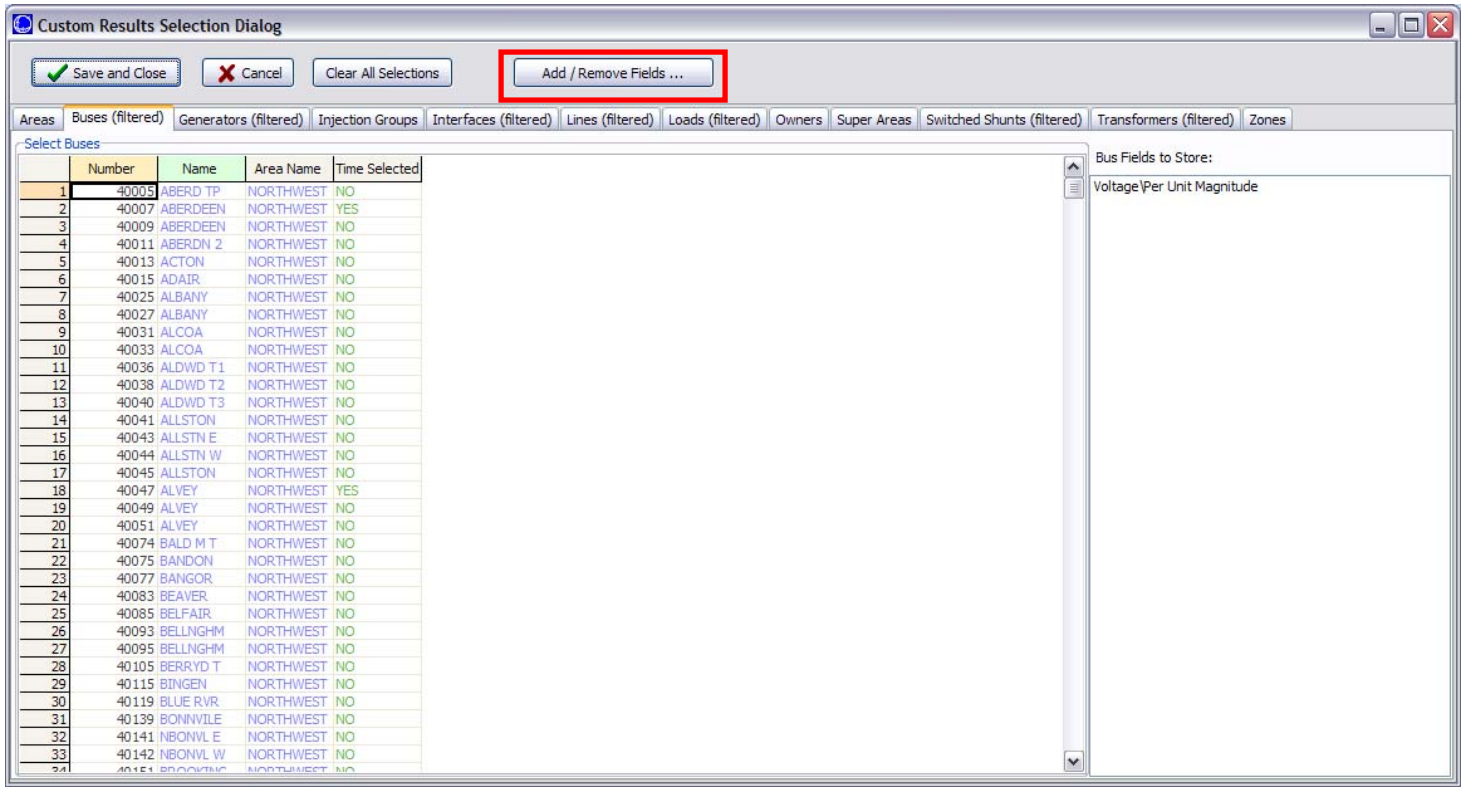
Time Step Simulation Tool - Overview

- Values to monitor during the simulation are specified in the Results tab.



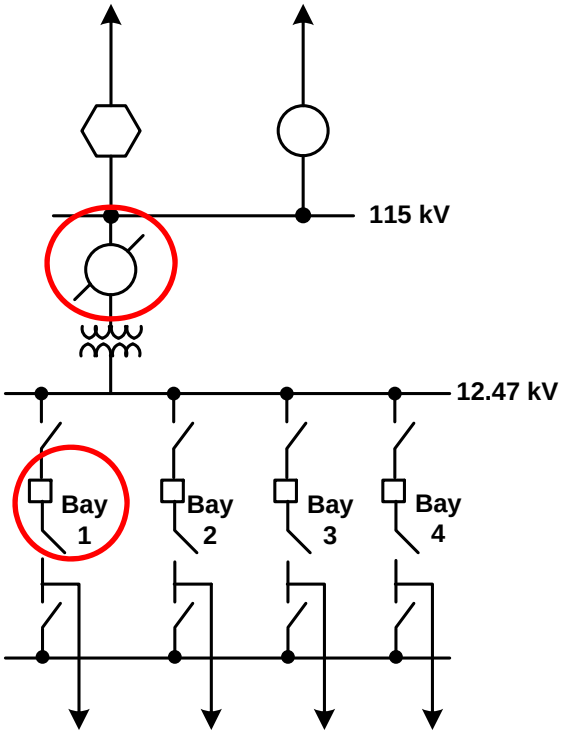
Time Step Simulation Tool - Overview

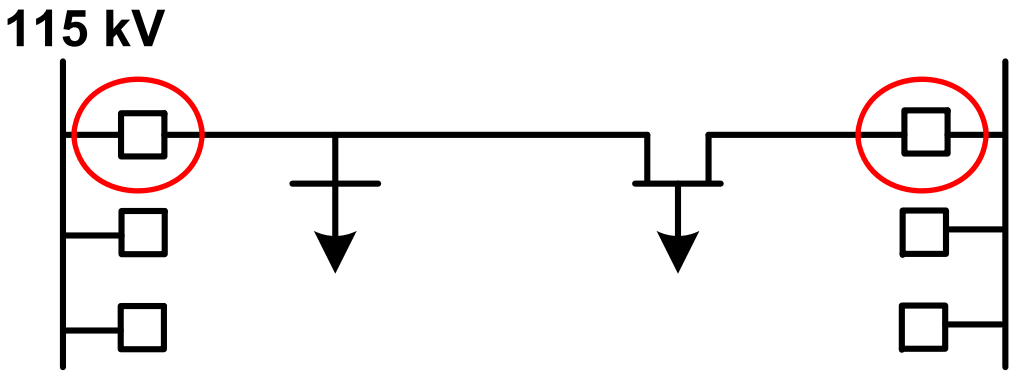
- Elements are selected by choosing View/Modify and setting the Time Selected field to “Yes”.
- Add/Remove Fields allows the values to monitor for each element to be selected



Modeling UVLS Relays

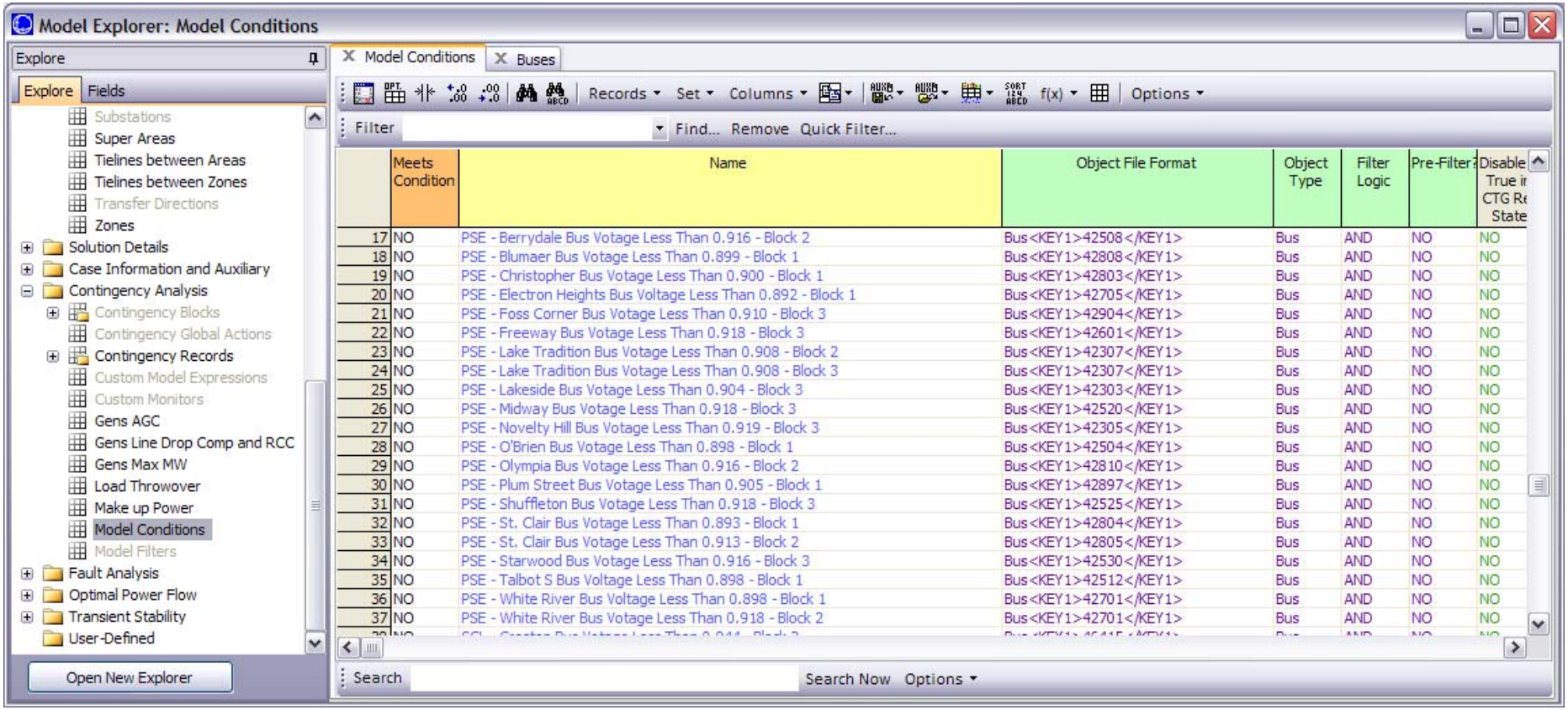
- UVLS relays operate in several different ways





Modeling UVLS Relays

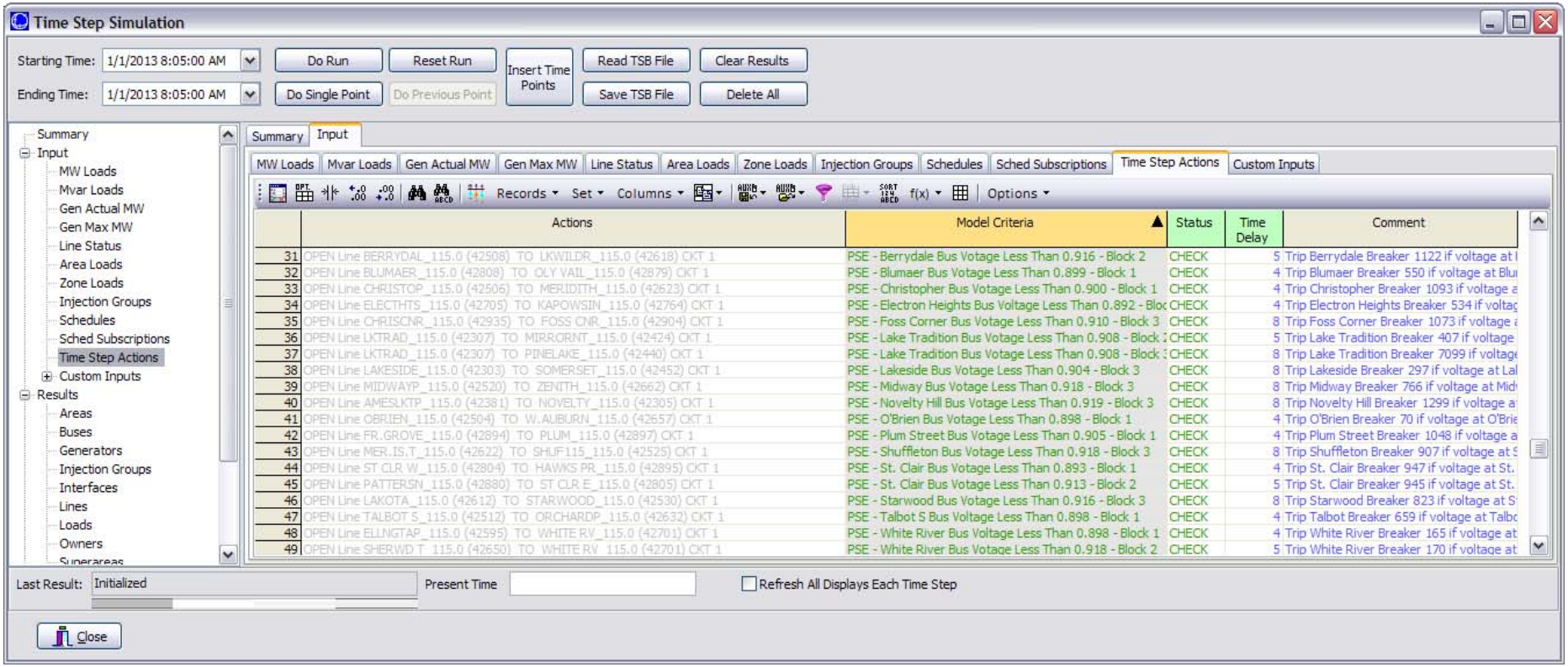
- Relay voltage set-points are modeled as Model Conditions



	Meets Condition	Name	Object File Format	Object Type	Filter Logic	Pre-Filter?	Disable True in CTG Re State
17	NO	PSE - Berrydale Bus Votage Less Than 0.916 - Block 2	Bus<KEY1>42508</KEY1>	Bus	AND	NO	NO
18	NO	PSE - Blumaer Bus Votage Less Than 0.899 - Block 1	Bus<KEY1>42808</KEY1>	Bus	AND	NO	NO
19	NO	PSE - Christopher Bus Votage Less Than 0.900 - Block 1	Bus<KEY1>42803</KEY1>	Bus	AND	NO	NO
20	NO	PSE - Electron Heights Bus Voltage Less Than 0.892 - Block 1	Bus<KEY1>42705</KEY1>	Bus	AND	NO	NO
21	NO	PSE - Foss Corner Bus Votage Less Than 0.910 - Block 3	Bus<KEY1>42904</KEY1>	Bus	AND	NO	NO
22	NO	PSE - Freeway Bus Votage Less Than 0.918 - Block 3	Bus<KEY1>42601</KEY1>	Bus	AND	NO	NO
23	NO	PSE - Lake Tradition Bus Votage Less Than 0.908 - Block 2	Bus<KEY1>42307</KEY1>	Bus	AND	NO	NO
24	NO	PSE - Lake Tradition Bus Votage Less Than 0.908 - Block 3	Bus<KEY1>42307</KEY1>	Bus	AND	NO	NO
25	NO	PSE - Lakeside Bus Votage Less Than 0.904 - Block 3	Bus<KEY1>42303</KEY1>	Bus	AND	NO	NO
26	NO	PSE - Midway Bus Votage Less Than 0.918 - Block 3	Bus<KEY1>42520</KEY1>	Bus	AND	NO	NO
27	NO	PSE - Novelty Hill Bus Votage Less Than 0.919 - Block 3	Bus<KEY1>42305</KEY1>	Bus	AND	NO	NO
28	NO	PSE - O'Brien Bus Votage Less Than 0.898 - Block 1	Bus<KEY1>42504</KEY1>	Bus	AND	NO	NO
29	NO	PSE - Olympia Bus Votage Less Than 0.916 - Block 2	Bus<KEY1>42810</KEY1>	Bus	AND	NO	NO
30	NO	PSE - Plum Street Bus Votage Less Than 0.905 - Block 1	Bus<KEY1>42897</KEY1>	Bus	AND	NO	NO
31	NO	PSE - Shuffleton Bus Votage Less Than 0.918 - Block 3	Bus<KEY1>42525</KEY1>	Bus	AND	NO	NO
32	NO	PSE - St. Clair Bus Votage Less Than 0.893 - Block 1	Bus<KEY1>42804</KEY1>	Bus	AND	NO	NO
33	NO	PSE - St. Clair Bus Votage Less Than 0.913 - Block 2	Bus<KEY1>42805</KEY1>	Bus	AND	NO	NO
34	NO	PSE - Starwood Bus Votage Less Than 0.916 - Block 3	Bus<KEY1>42530</KEY1>	Bus	AND	NO	NO
35	NO	PSE - Talbot S Bus Voltage Less Than 0.898 - Block 1	Bus<KEY1>42512</KEY1>	Bus	AND	NO	NO
36	NO	PSE - White River Bus Voltage Less Than 0.898 - Block 1	Bus<KEY1>42701</KEY1>	Bus	AND	NO	NO
37	NO	PSE - White River Bus Votage Less Than 0.918 - Block 2	Bus<KEY1>42701</KEY1>	Bus	AND	NO	NO

Modeling UVLS Relays

- Relay trip times and loads to trip are modeled as Time Step Actions in the TSS Tool

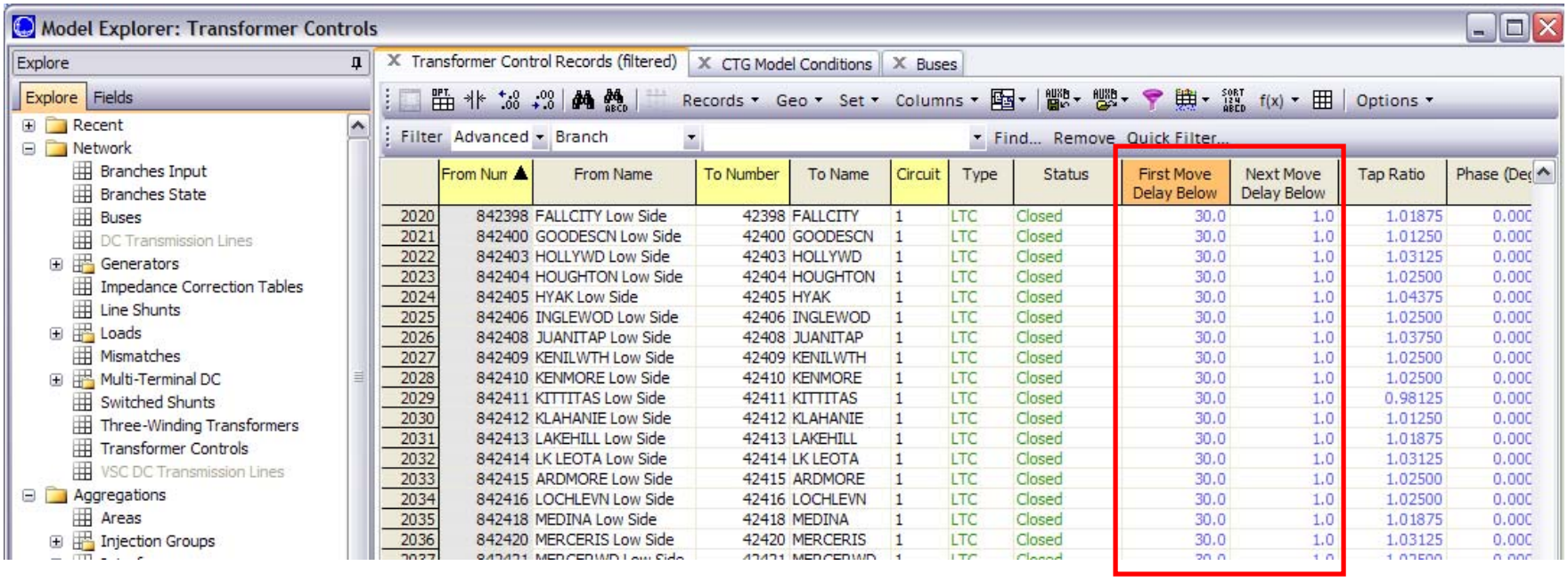


Additional Considerations

- Typical powerflow studies model voltage regulation on the transmission system transformers and allow automatic operation of capacitor banks
  - This option is disabled as part of post-transient methodology
- With CMPLDW, transmission transformers and switched shunts are modeled as fixed and distribution transformers are modeled as load tap changing
- 500 kV switched shunts which operate automatically on a known time delay are modeled to reflect automatic operation

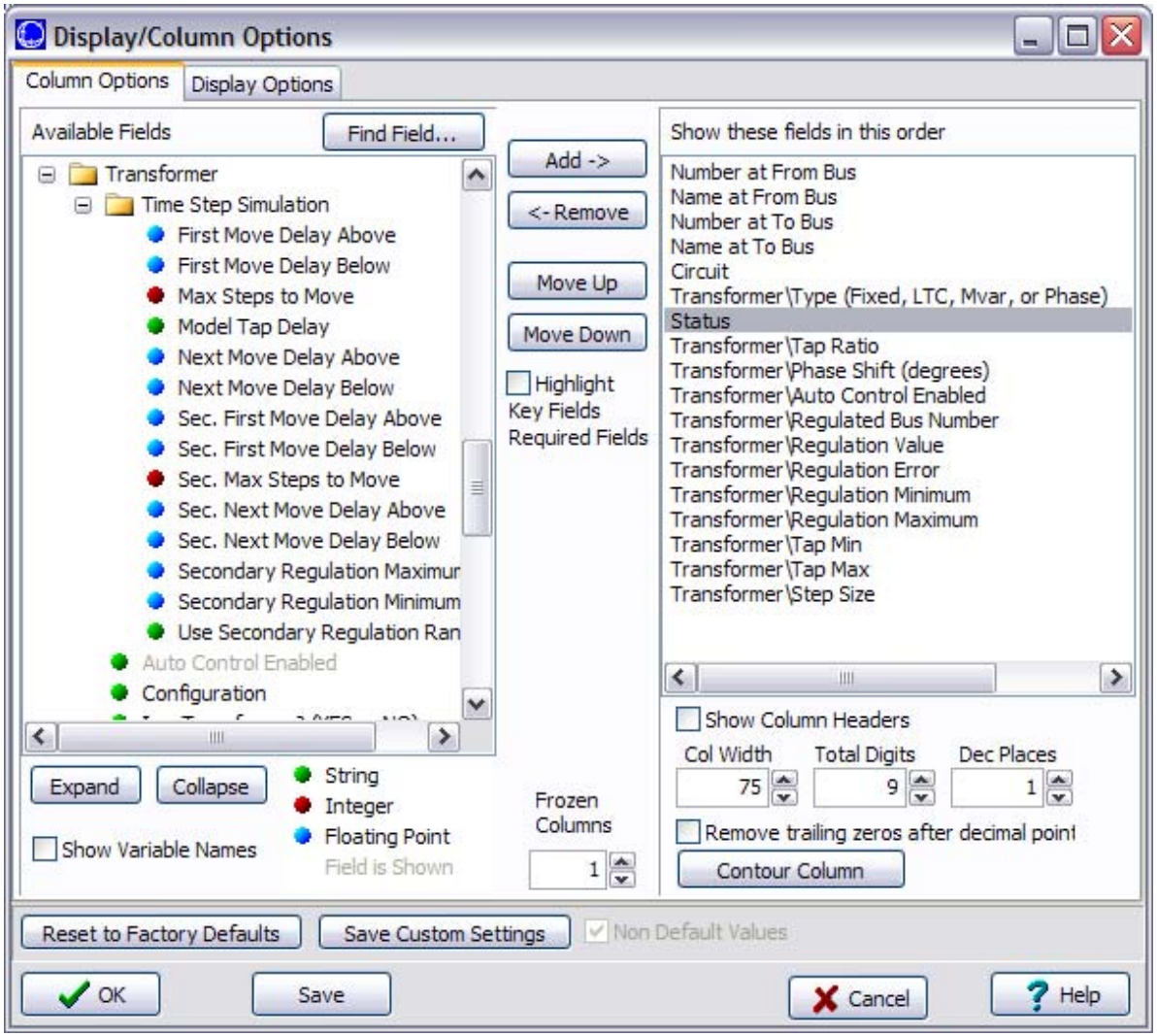
Additional Considerations

- Distribution transformers are modeled as LTCs with a 30 second delay in LTC action following voltage excursion outside of dead band and resulting tap changes every 2 seconds



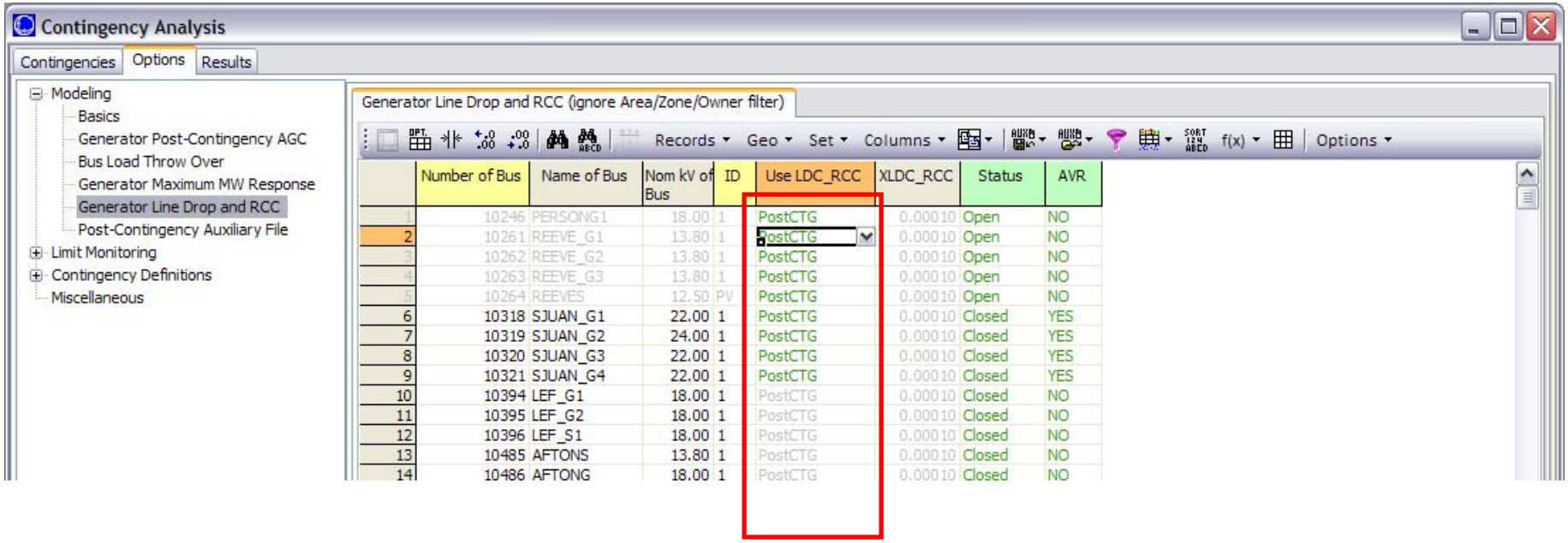
	From Num	From Name	To Number	To Name	Circuit	Type	Status	First Move Delay Below	Next Move Delay Below	Tap Ratio	Phase (Deg
2020	842398	FALLCITY Low Side	42398	FALLCITY	1	LTC	Closed	30.0	1.0	1.01875	0.000
2021	842400	GOODESCN Low Side	42400	GOODESCN	1	LTC	Closed	30.0	1.0	1.01250	0.000
2022	842403	HOLLYWD Low Side	42403	HOLLYWD	1	LTC	Closed	30.0	1.0	1.03125	0.000
2023	842404	HOUGHTON Low Side	42404	HOUGHTON	1	LTC	Closed	30.0	1.0	1.02500	0.000
2024	842405	HYAK Low Side	42405	HYAK	1	LTC	Closed	30.0	1.0	1.04375	0.000
2025	842406	INGLEWOD Low Side	42406	INGLEWOD	1	LTC	Closed	30.0	1.0	1.02500	0.000
2026	842408	JUANITAP Low Side	42408	JUANITAP	1	LTC	Closed	30.0	1.0	1.03750	0.000
2027	842409	KENILWTH Low Side	42409	KENILWTH	1	LTC	Closed	30.0	1.0	1.02500	0.000
2028	842410	KENMORE Low Side	42410	KENMORE	1	LTC	Closed	30.0	1.0	1.02500	0.000
2029	842411	KITTITAS Low Side	42411	KITTITAS	1	LTC	Closed	30.0	1.0	0.98125	0.000
2030	842412	KLAHANIE Low Side	42412	KLAHANIE	1	LTC	Closed	30.0	1.0	1.01250	0.000
2031	842413	LAKEHILL Low Side	42413	LAKEHILL	1	LTC	Closed	30.0	1.0	1.01875	0.000
2032	842414	LK LEOTA Low Side	42414	LK LEOTA	1	LTC	Closed	30.0	1.0	1.03125	0.000
2033	842415	ARDMORE Low Side	42415	ARDMORE	1	LTC	Closed	30.0	1.0	1.02500	0.000
2034	842416	LOCHLEVN Low Side	42416	LOCHLEVN	1	LTC	Closed	30.0	1.0	1.02500	0.000
2035	842418	MEDINA Low Side	42418	MEDINA	1	LTC	Closed	30.0	1.0	1.01875	0.000
2036	842420	MERCERIS Low Side	42420	MERCERIS	1	LTC	Closed	30.0	1.0	1.03125	0.000

Additional Considerations



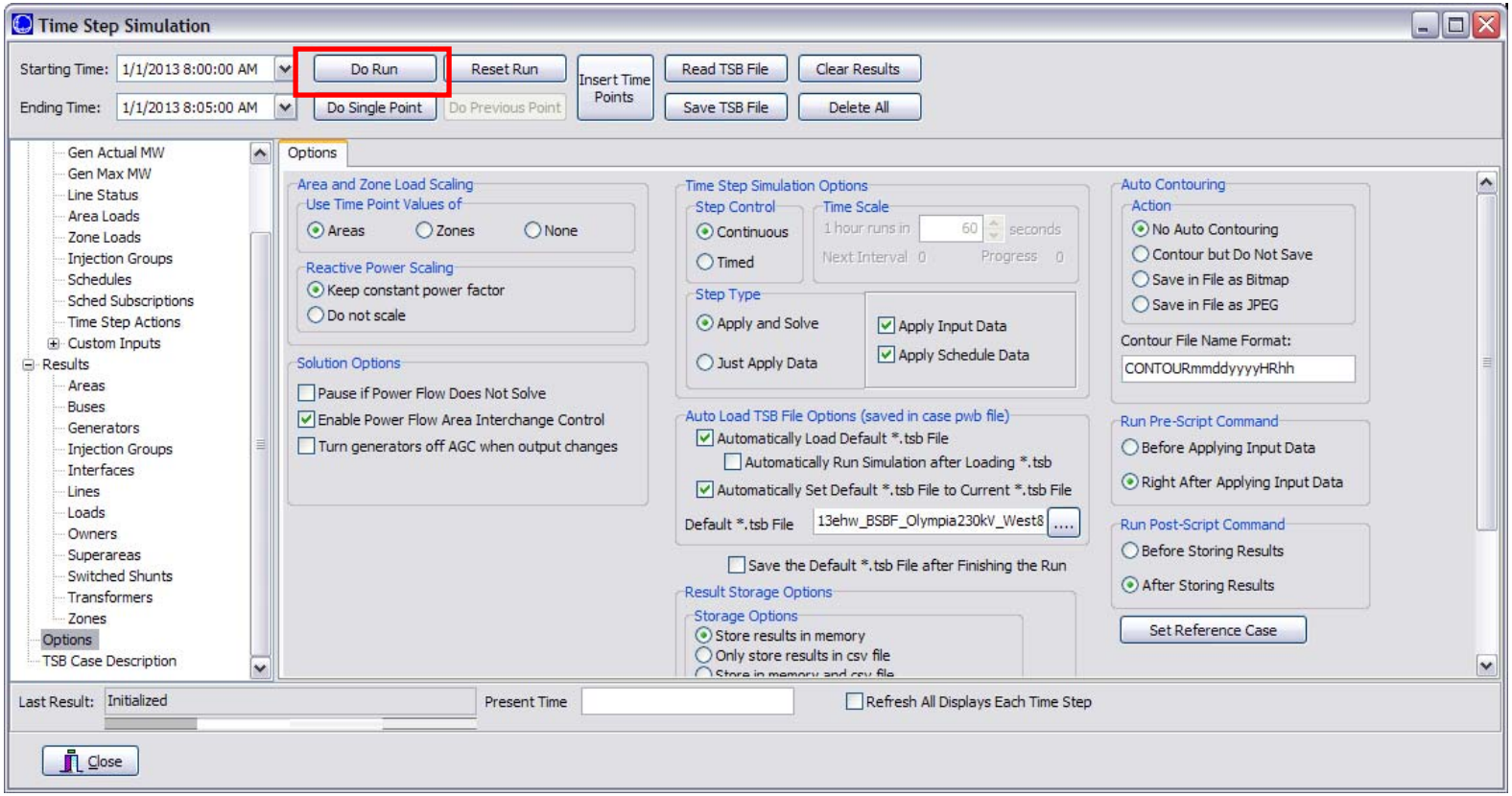
Additional Considerations

- Generator line drop and reactive current compensation is activated
  - More realistic method of generator voltage control - generator will regulate its terminal voltage
    - Post-transient study methodology includes this action
  - Available in Contingency Analysis Dialog



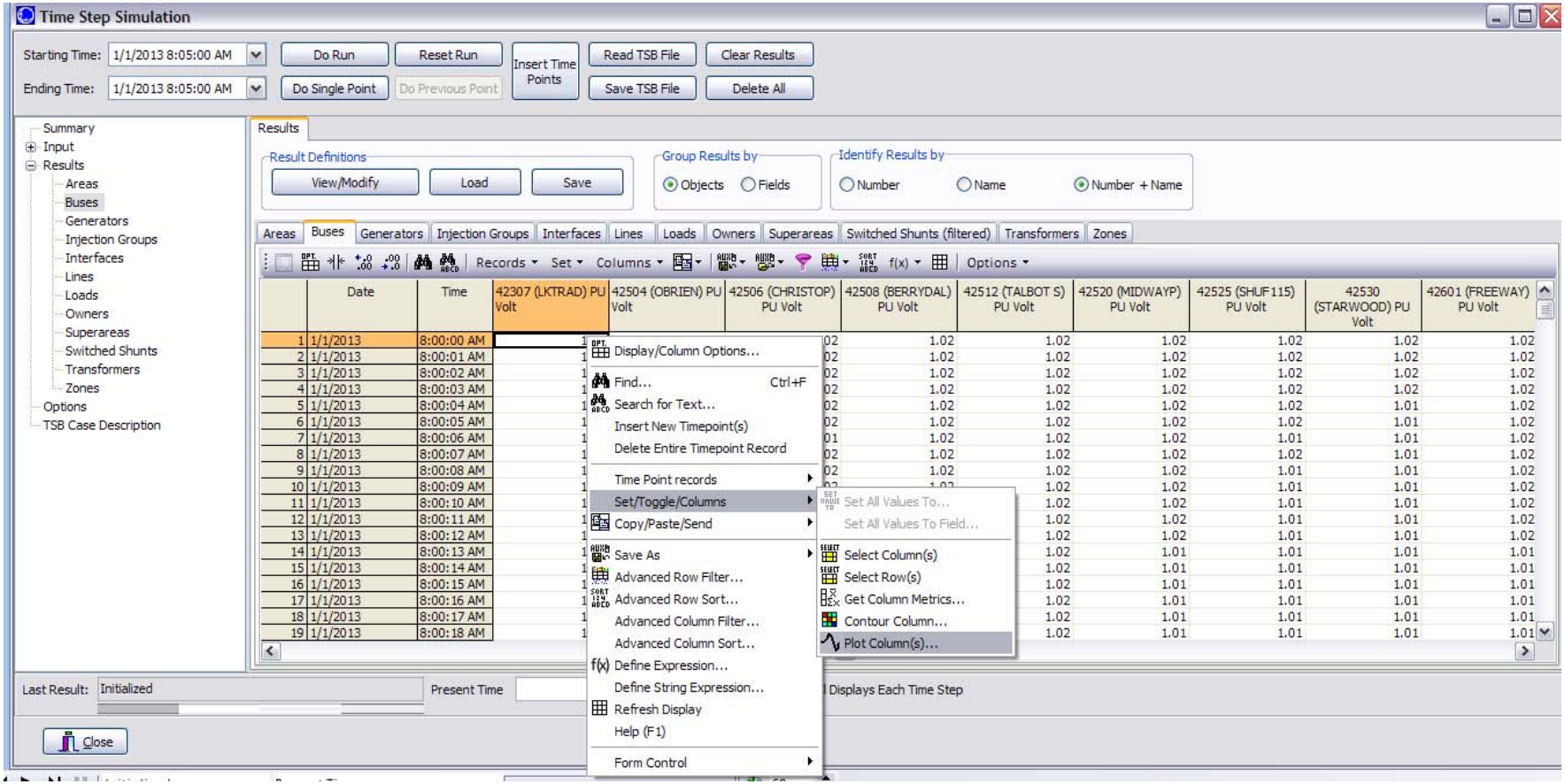
Running the Time Step Simulation

- Additional setting are chosen from the ‘Options’ menu (i.e. pause simulation if the solution diverges, results storage, etc.)
- The Time Step Simulation is run by choosing ‘Do Run’ from the TSS menu



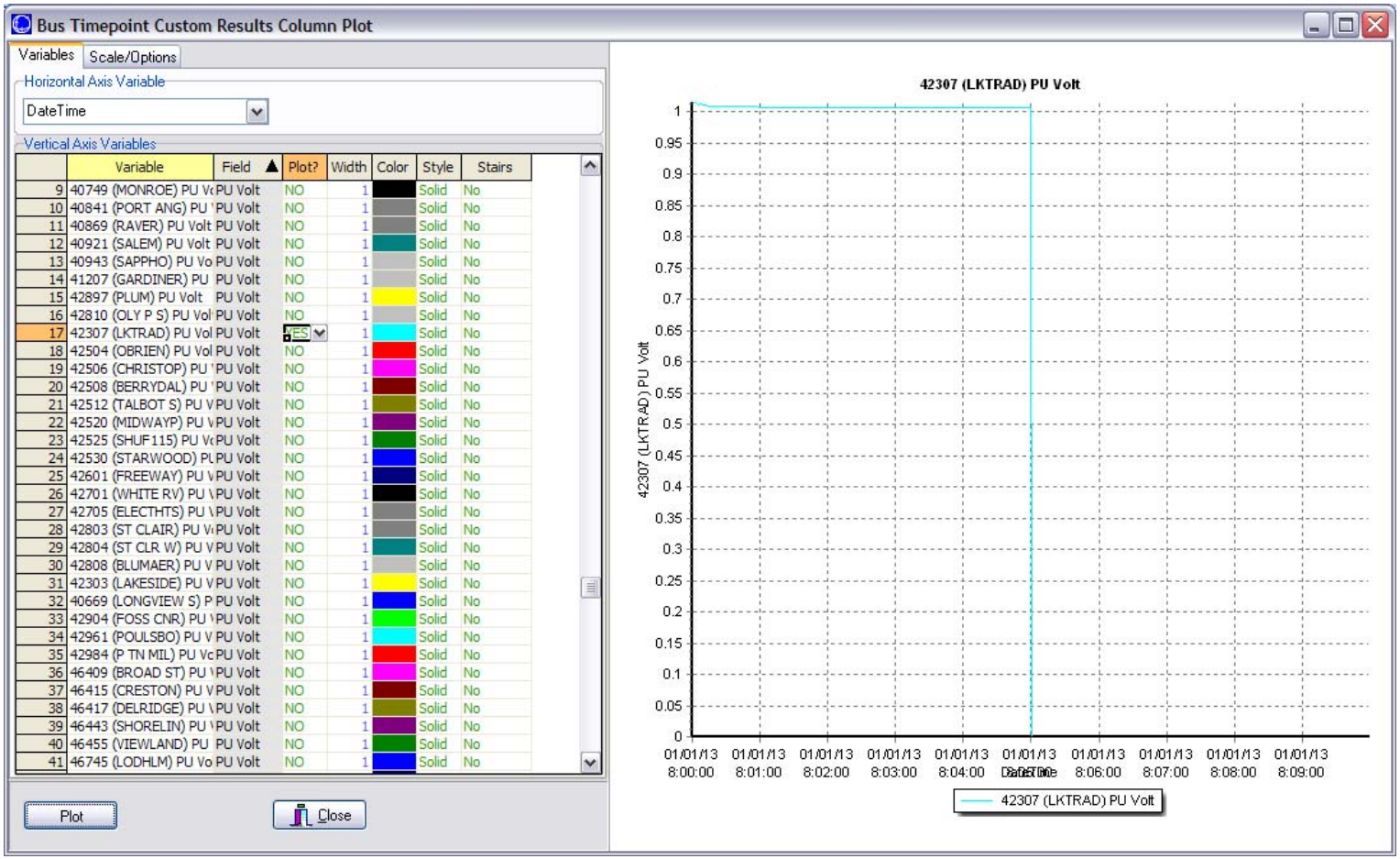
Plotting the Results

- Results can be plotted by right clicking on the column to plot and choosing Set/Toggle/Columns > Plot Column(s)



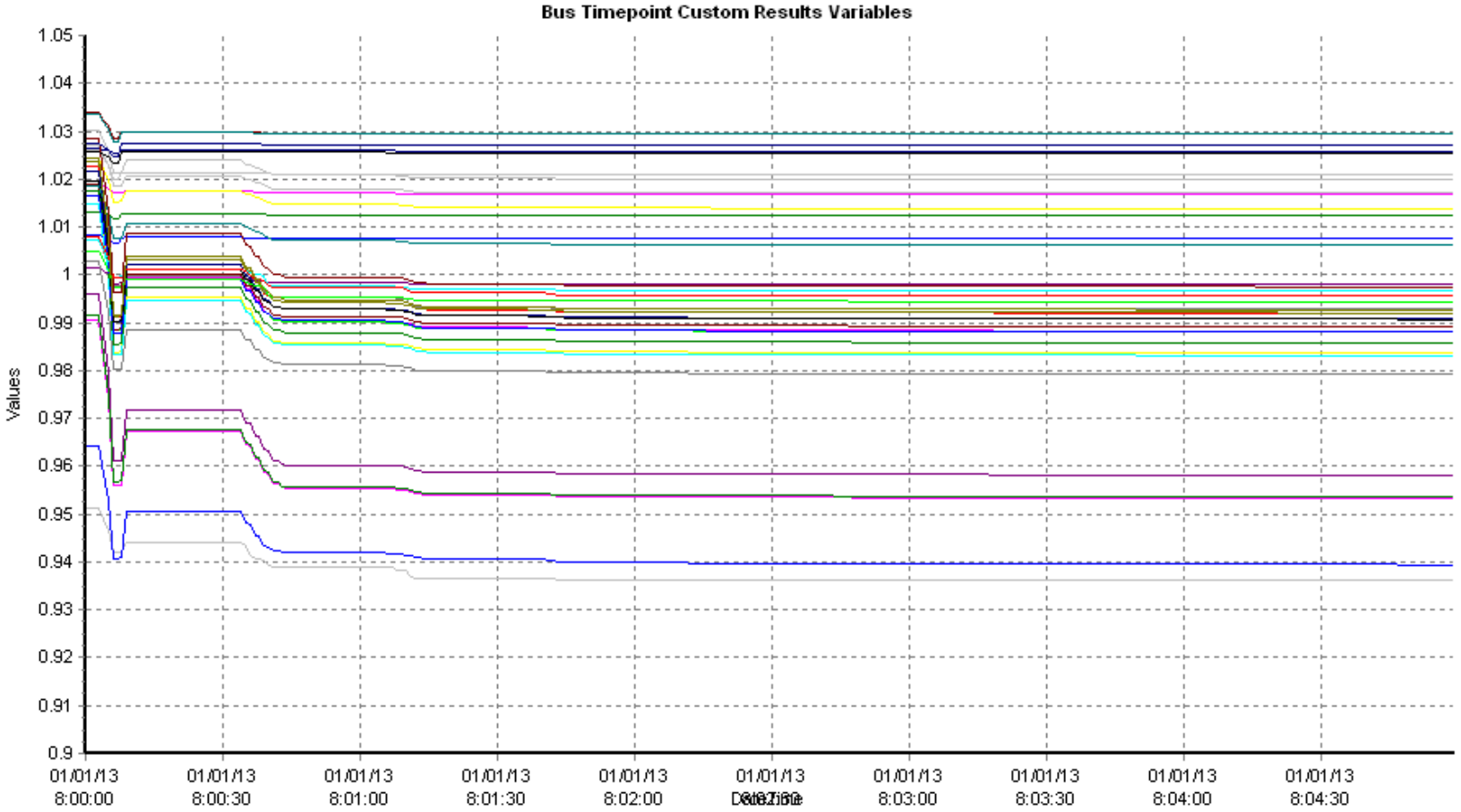
Plotting the Results

- To plot multiple values, either choose multiple columns from the Results window or change the value in the Plot? Column to “Yes”.



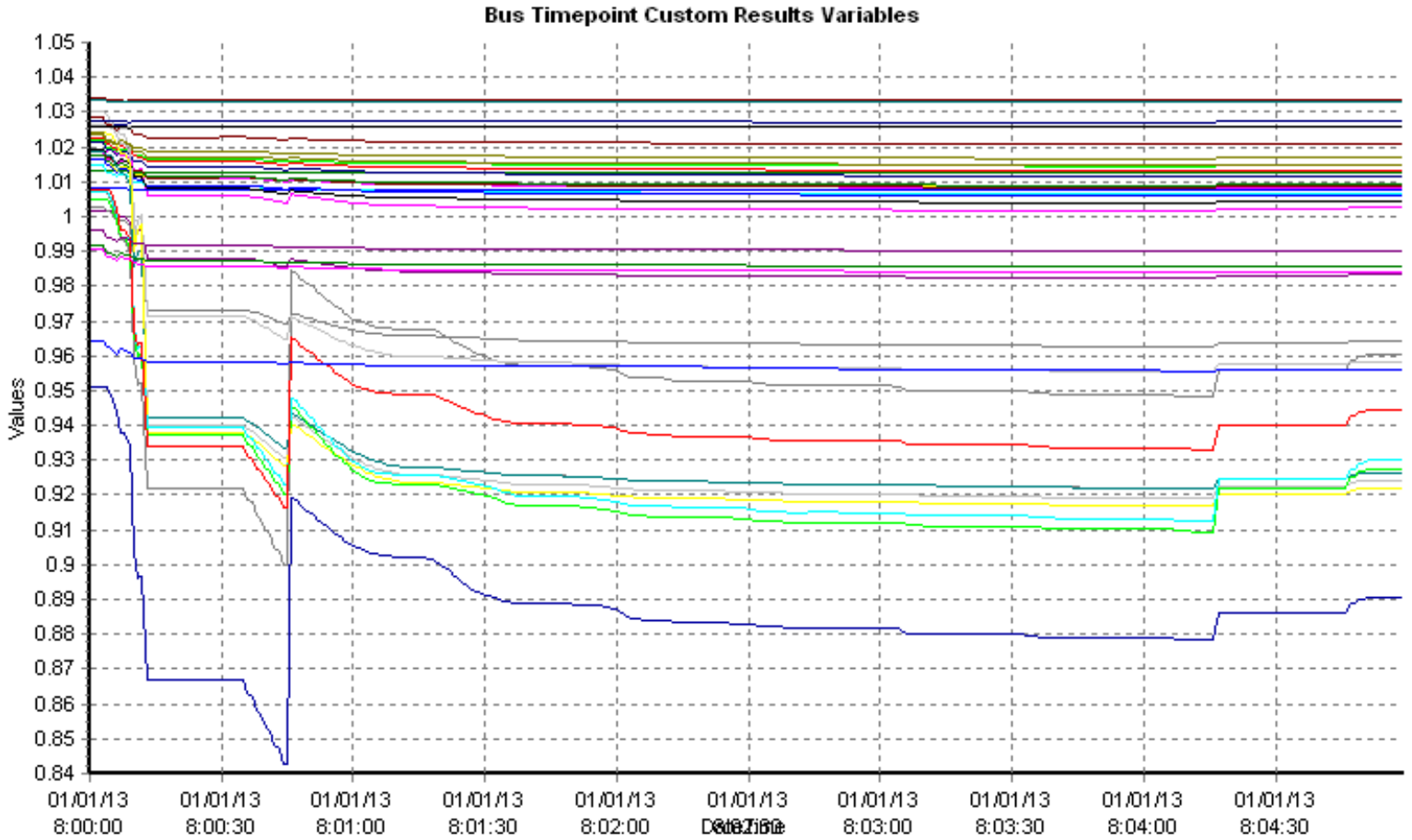
Study Results

- Voltage sensitive load characteristics can be seen when plotting BES bus voltage



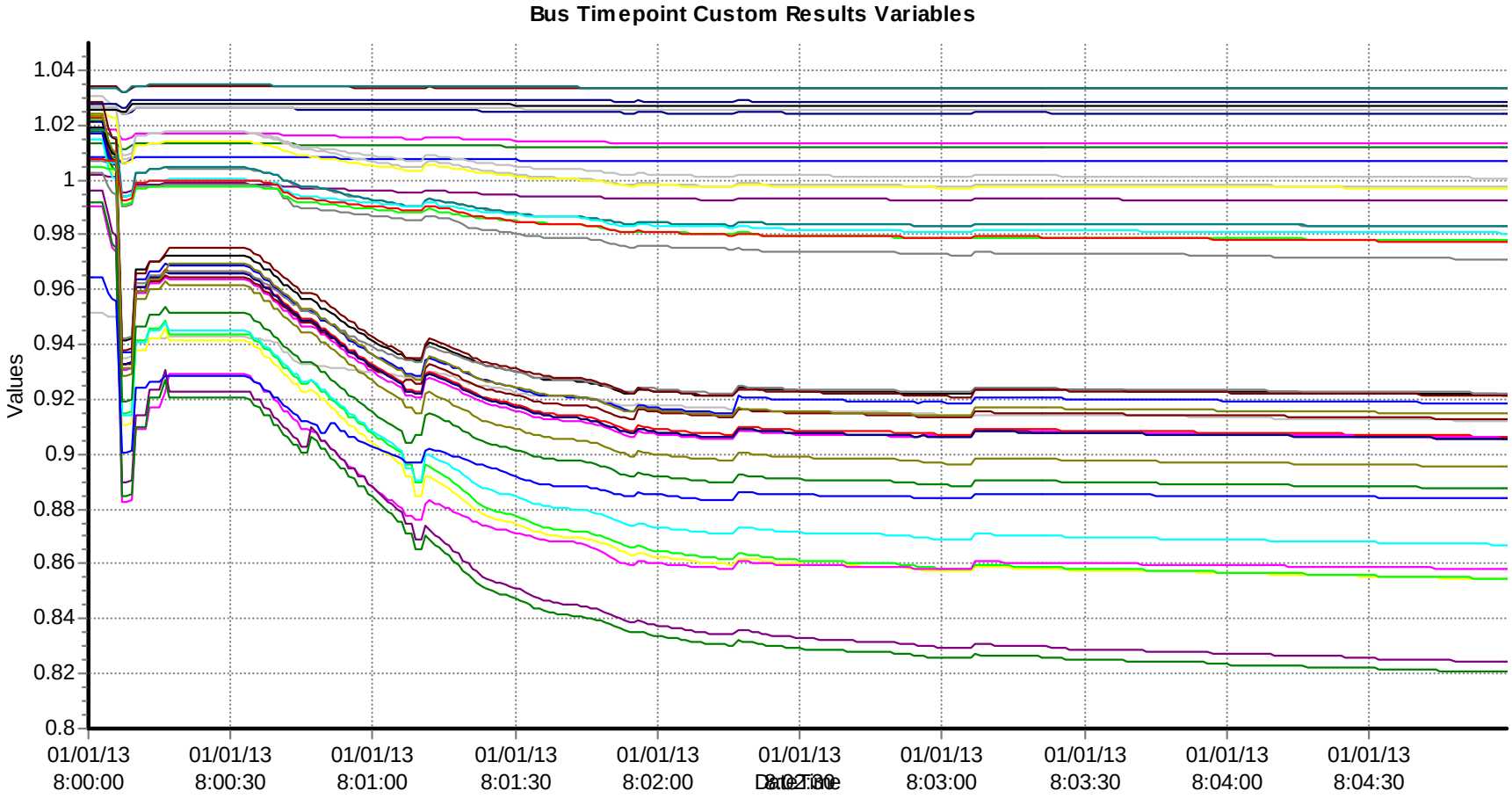
Study Results

- When loads are tripped, this action may be apparent by plotting bus voltage



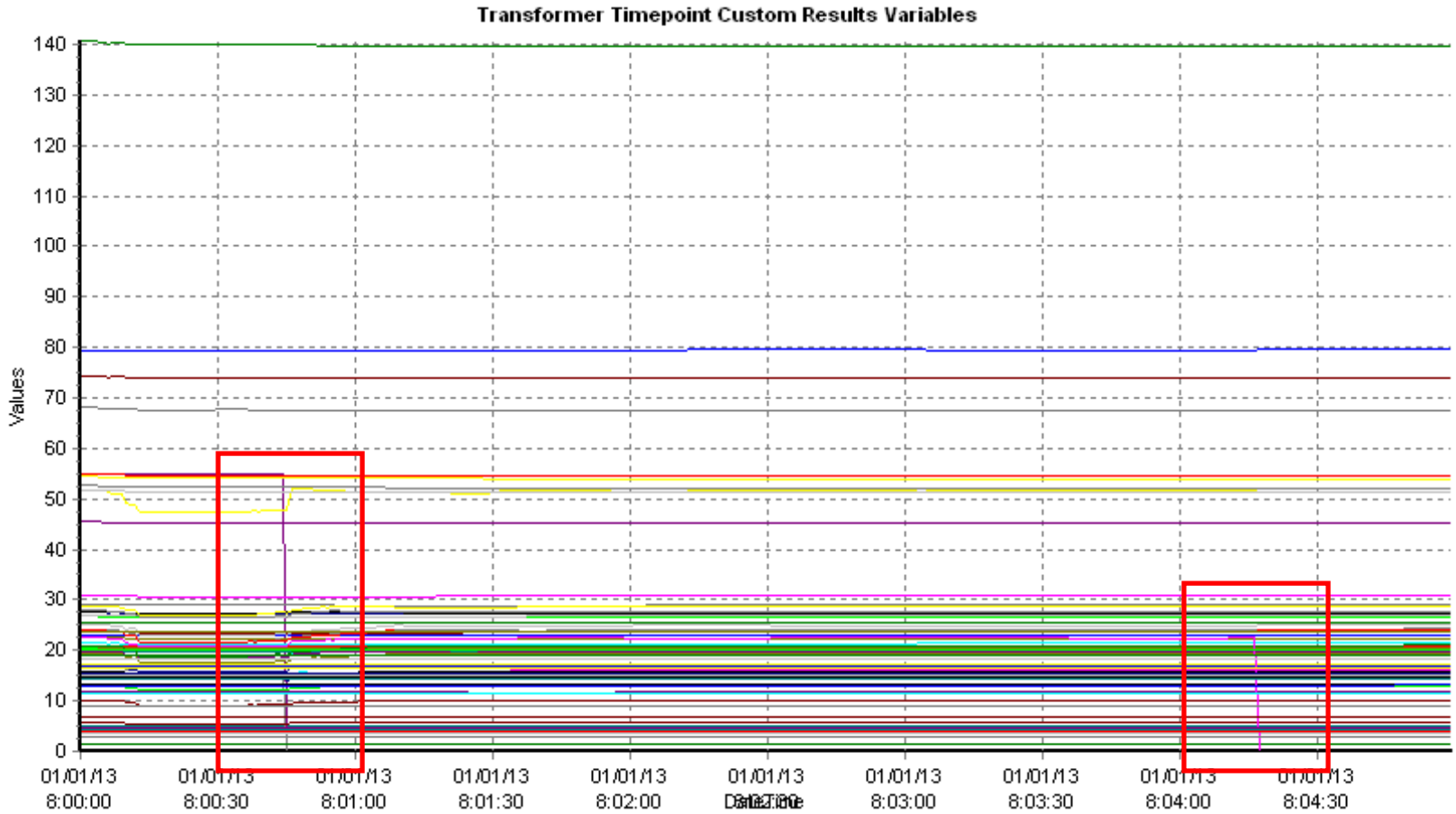
Study Results

- Some scenarios resulted in extremely low voltages across the Puget Sound Area



Study Results

- Plot of MW flow through distribution transformers can also be used to determine whether load is tripped



Challenges

- Tripping a fraction of a load is currently not possible with the Composite Load Model.
  - Load was broken up into corresponding blocks prior to implementing composite load model
- Considerable manual work is involved in plotting results and investigating whether load shedding occurred

Questions???

Conclusion

- The PowerWorld Time Step Simulation Tool was a valuable tool for performing this study
  - Ability to model distribution LTC transformers
  - Voltage sensitive load characteristics demonstrated with composite load model