Steady-State Power System Security Analysis with PowerWorld Simulator

S2: Advanced Power Flow using PowerWorld Simulator

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Overview

- Detailed Overview of “Single Solution”
  - Pre-Processing
  - MW Control Loop
  - Voltage Control Loop
  - Inner Power Flow Loop

- Power Flow Solution Advanced Options
  - Minimum Per Unit Voltage for Constant Power and Current Loads
  - Parallel Tap Balancing
  - Regulation Range Correction
  - Minimum Tap Sensitivity
  - Generator Mvar Sharing
  - Switched Shunt and Transformer Solution Options
- Area Control with Multiple Islands
- Solution Diagnosis Aids

What Does It Mean to do a Single Solution in Simulator?

- Single solution should not be confused with a single Newton-Raphson (or other technique) power flow
- Simulator's "Single Solution" encompasses three nested loops that iterate between a power flow routine, logic for control device switching, and generation control until the power flow is solved and no more device switching is detected

Overview of Single Solution Routine

- Pre-processing
  - Angle Smoothing
  - Generator remote regulation viability
  - Estimate MW change needed
- Three Nested Loops Solution Process
  - MW Control Loop
    - Voltage Controller Loop
      - Inner Power Flow loop

Note: The Inner Power Flow Loop was covered in S1

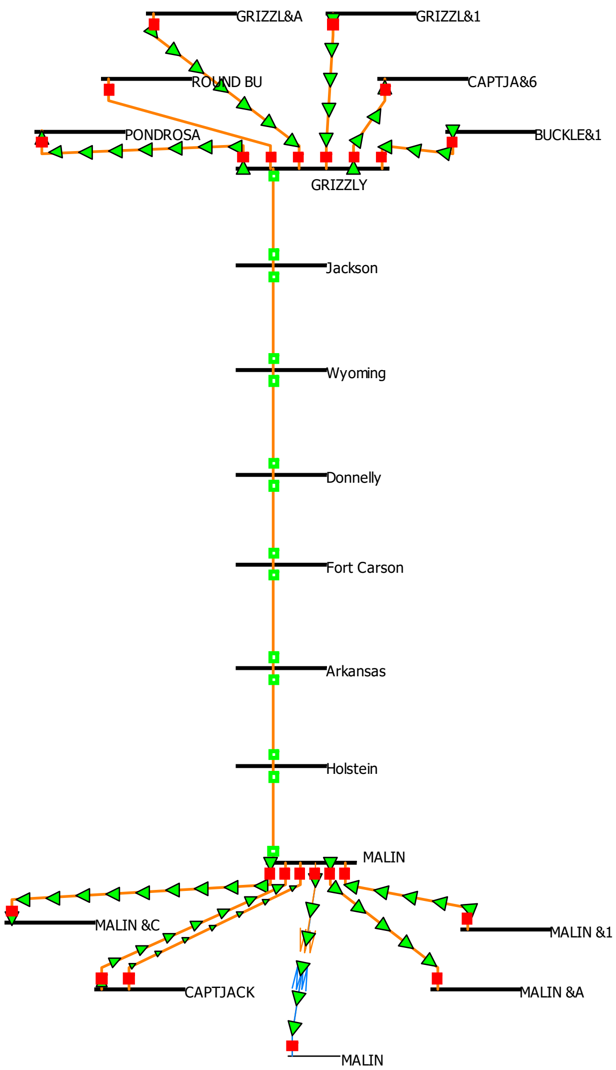
Traditionally called the *Power Flow Solution*

Voltage Control Loop covered in this section

MW Control Loop covered later

Pre-processing

- Angle Smoothing
  - Reduces large angle differences across transmission elements that have recently been closed to reduce initial power flow mismatches
  - If disabled, closing a line with a large angle difference often causes the power flow to diverge
  - Angle smoothing also works for a series of branches that are closed together
- Following a topology change, Simulator also adjusts zero-magnitude voltages in groups of buses connected by low impedance branches



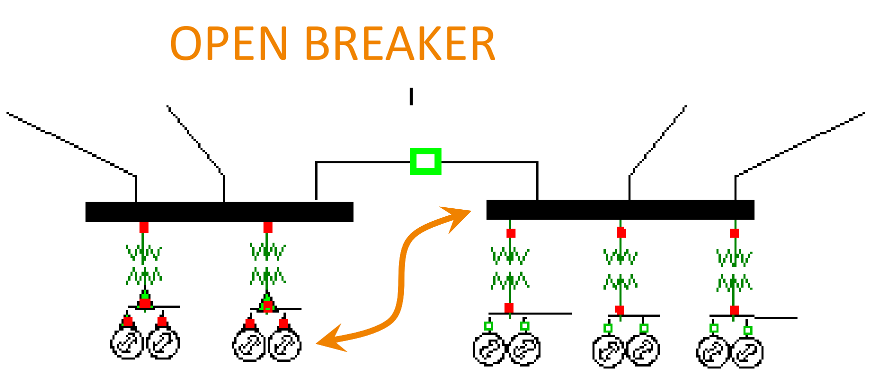
Pre-processing

- When pre-processing the voltage profile of a solution before solving, Simulator will now look at groupings of buses connected by very low impedances lines. If a bus in a grouping of energized buses has a zero voltage while other buses in the group do not, the zero voltage will be changed to the first non-zero voltage found in the grouping.

Pre-processing

- Generator Remote Regulation Viability
  - Checks for a viable transmission path between a generator bus and its remotely regulated bus
  - If a generator has no transmission path, or if all possible transmission routes to the regulated bus are intercepted by other voltage controlled buses, the generator is internally turned off of voltage regulation

If a generator on left is set to control voltage at the bus on the right, this would cause convergence difficulty



Pre-processing

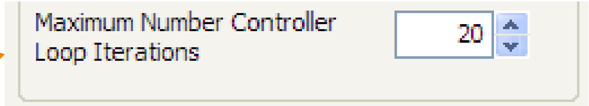
- Estimate MW Change
  - Stores the initial output of the generators for referencing during participation factor control
  - Modifies generator outputs in each area, super area, or island (depending on what control is being used) to meet approximate ACE requirements
  - Attempting to prevent slack bus from changing by drastic amounts during the first Newton-Raphson power flow calculation in the inner loop

MW Control Loop

- MW Control (Outer Loop)
  - Repeat
    - Voltage Controller Loop
      - Inner Power Flow Loop
    - Change generation/load to meet ACE requirements
      - Redispatches generation and/or load using the selected AGC control method for each area (Super area or island)
  - Until no more generation/load changes are required

Power Flow and Control Loop

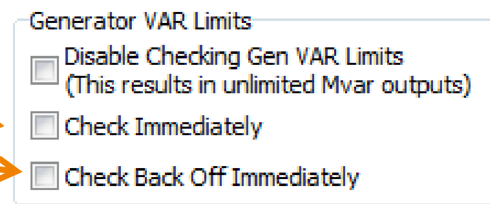
- Voltage control switching and Inner Power Flow Loop
  - Repeat
    - 1: Inner Power Flow loop
      - 1a: Continuous SVC Switching
    - 2: Generator MVAR Limit Checking
    - 3: DC Line Solution
    - 4: Switched Shunt Switching
    - 5: Discrete SVC Switching
    - 6: Transformer Switching
    - 7: D-FACTS Switching



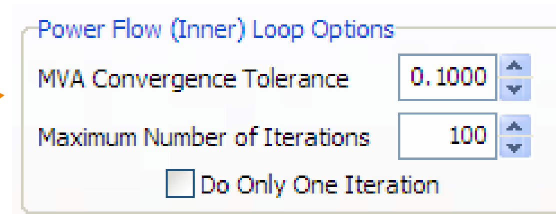
  - Until no more control switching is required or maximum control loop iterations reached

Step 1: Inner Power Flow Loop
Step 1a: Continuous SVC Control

- Step 1: Inner Power Flow loop, Repeat…
  - Evaluate Mismatch
  - Generator MVAR output automatically calculated for PV buses
  - SVC MVAR output automatically calculated for continuous SVCs
  - Optionally (enforce Generator MVAR limits at each step)
  - Optionally (allow generators to only back off Mvar limits)
  - Perform power flow step
    - » Newton's Method (this is in rectangular form)
    - » Decoupled Power Flow
    - » Polar Form Newton's Method



- …Until no mismatch



- Step 1a: Continuous SVC Limit Check and Discrete Component Switching
  - Check MVAR limits on continuous SVCs
    - » SVSMO1 and SVSMO3
  - Switch any fixed shunts controlled by continuous SVCs
  - Goto Step 1 if any SVCs or controlled fixed shunts move

Step 2: Generator MVAR Limits
Step 3: Solve DC line equations

- Step 2: Generator MVAR Limit Check
  - Backs off or enforces MVAR limits
  - Checks for controller oscillation
    - » Generators that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors
    - » Incorporates voltage vector changes by processing each generator
- Step 3: Solve DC line equations
  - DC Lines will be discussed later, but to the power flow solution they look like a fixed MW injection with a Mvar injection that is a function of the AC line terminal voltages

Step 4: Switched Shunt Control

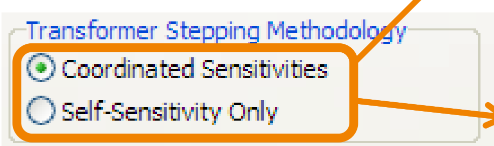
- Step 4: Switched shunt control
  - Checks regulated buses for voltage limit violations and adjusts switched shunt control appropriately
    - » Also can control the total VAR output for generators controlling the voltage at a particular bus (good for modeling a shunt that maintains VAR reserves)
    - » Shunts are adjusted one at a time with each shunt only considering its impact on the regulated bus' voltage. The interaction between different shunts is not modeled here.
  - Checks for controller oscillations
    - » Switched shunts that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors

Step 5: Discrete SVC Control

- Step 5: Discrete SVC Control
  - Only SVCs that are discrete-type SVCs are switched in this step
    - » SVSMO2
  - Checks regulated buses for voltage limit violations and adjusts SVC control appropriately
    - » Any fixed shunts controlled by the SVC are adjusted in this step
    - » SVCs are adjusted one at a time with each SVC only considering its impact on the regulated bus' voltage. The interaction between different SVCs is not modeled here.
  - Checks for controller oscillations
    - » SVCs that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors

Step 6: Transformer Switching

- Step 6: Transformer switching
  - Checks regulated Voltages, MVAR flows, and MW flows for limit violations and adjusts transformer controls in a manner dependent on the Transformer Stepping Methodology
    - » *Coordinated Sensitivities*: tap change calculation requires the construction and factorization of a full matrix dimensioned by the number of transformers which need to be switched. Normally a small number are changed.
    - » *Self-Sensitivity Only*: each transformer does not consider how it affects other transformers. This calculation is much faster, but may be less accurate and lead to more iterations
    - » Note: If more than 50 transformers are involved, Simulator always uses Self-Sensitivity Only
  - Checks for controller oscillations
    - » Transformers that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors

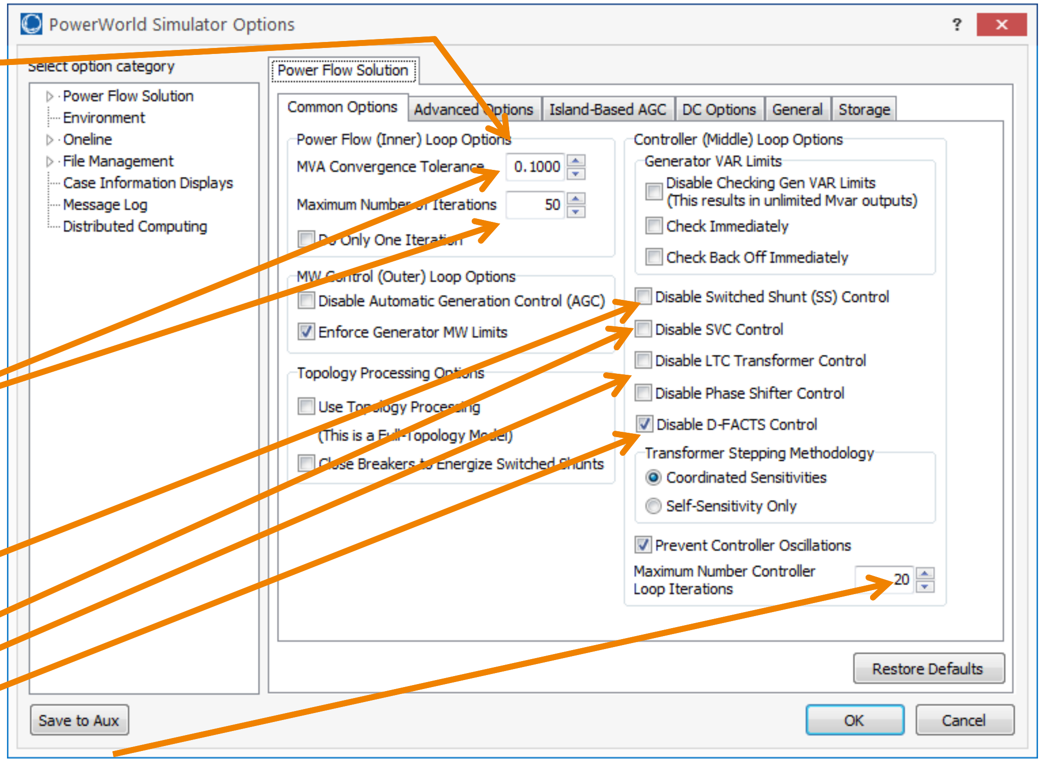


Step 7: D-FACTS Control

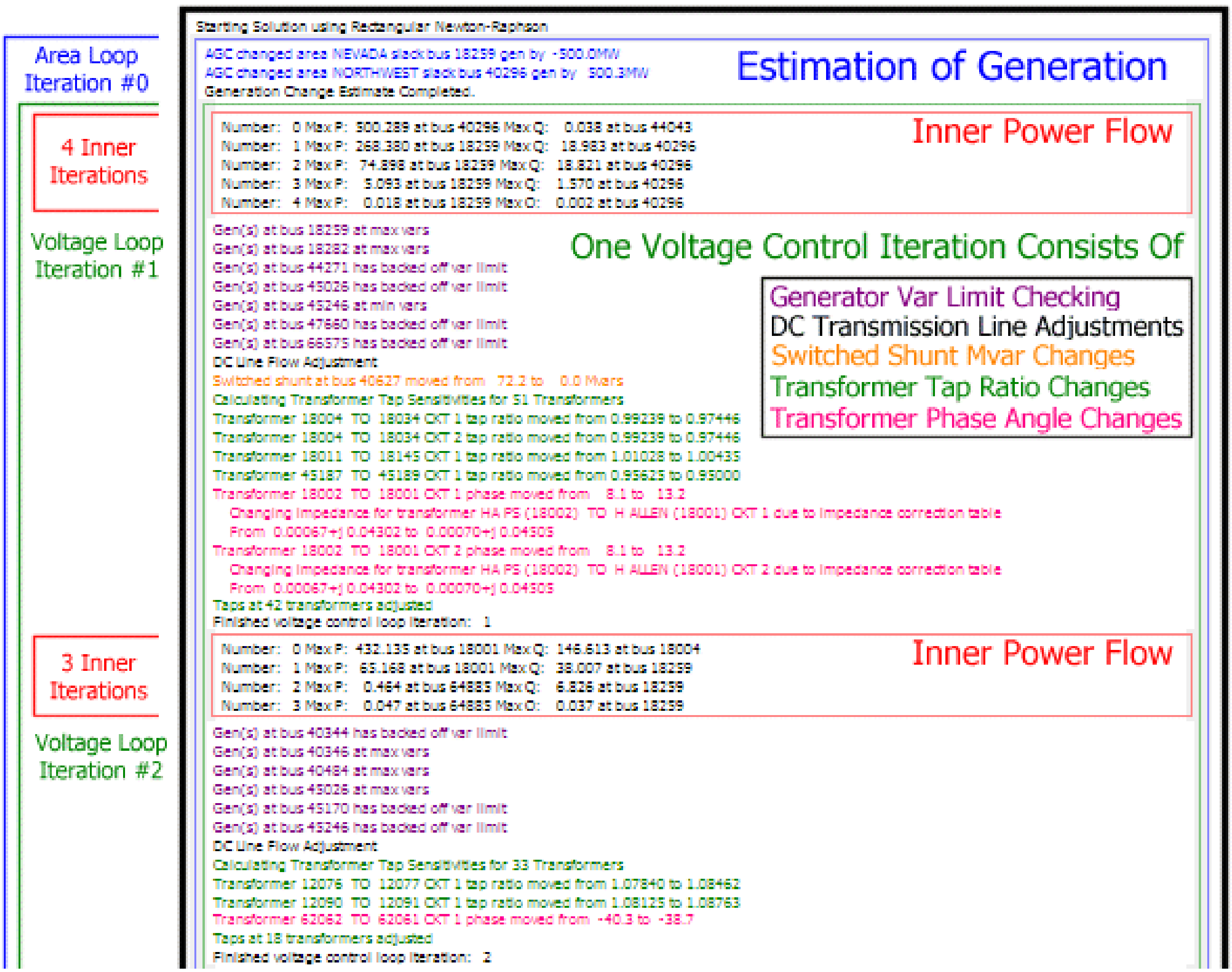
- Step 7: D-FACTS Control
  - D-FACTS devices attempt to keep the current on a branch within a specified range
  - Impedance of the D-FACTS is modified to adjust the current
  - D-FACTS that appear to be oscillating between control settings are internally set off of control
  - Updates Ybus with new impedance values

Complete Process

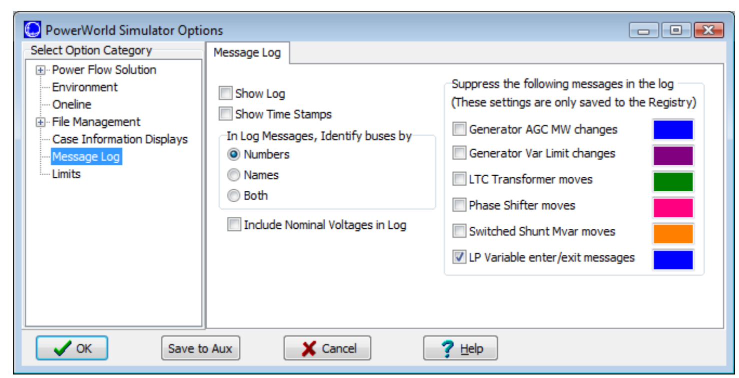
- Pre-processing
  - Angle Smoothing, Remote Viability Check, Area Generator Estimation
- Repeat (MW Control Loop)
  - Repeat (Controller Loop)
    - 1: Repeat (Inner Power Flow loop)
      - Evaluate Mismatch
      - Generator MVAR output automatically calculated for PV buses
      - SVC MVAR output automatically calculated for continuous SVCs
      - Optionally (enforce Generator MVAR limits at each step)
      - Optionally (allow generators to only back off Mvar limits)
      - Perform power flow step
        - » Newton's Method
        - » Decoupled Power Flow
        - » Polar Newton
    - Until no more mismatch (or max iteration)
      - 1a: Continuous SVC Limit Check and Discrete Component Switching
      - Goto Step 1 until no more SVC switching
    - 2: Generator MVAR Limit Checking
    - 3: DC Line Solution
    - 4: Switched Shunt Control Switching
    - 5: Discrete SVC Switching
    - 6: Transformer Switching
    - 7: D-FACTS Switching
  - Until no more control switching is required (or at max iteration)
  - Change generation/load to meet ACE requirements
    - Redispatches generation/load using the AGC control method for area (island)
- Until no more generation changes are required



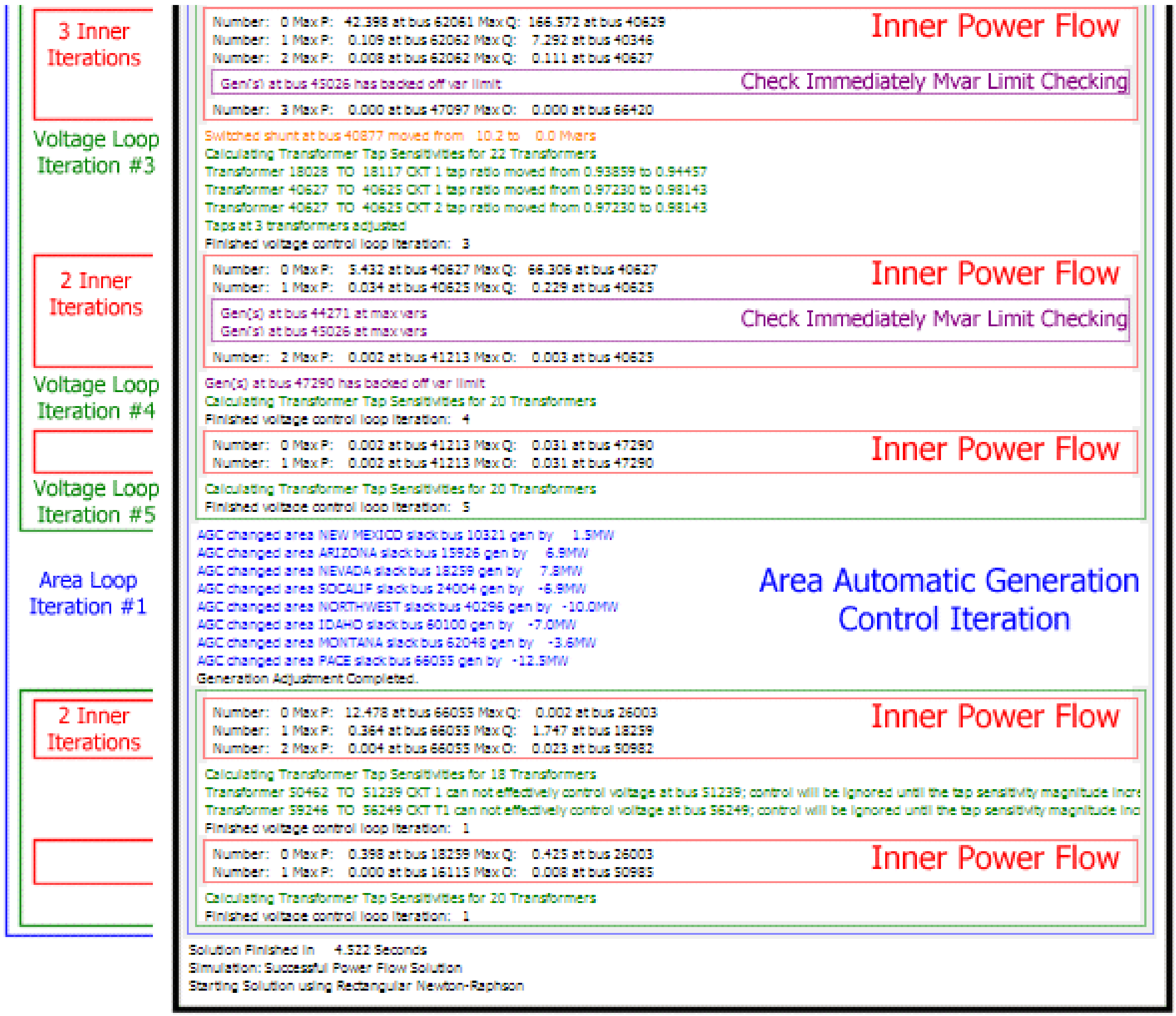
Example Message Log 1/2 (Image Only)



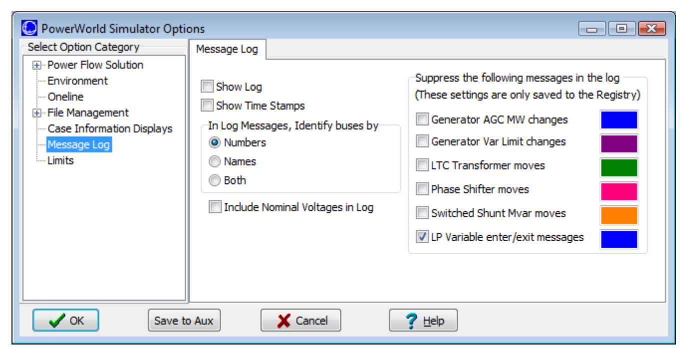
Colors of Messages determined by the Simulator, Message Log colors



Example Message Log 2/2 (Image Only)

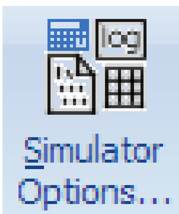


Colors of Messages determined by the Simulator, Message Log colors

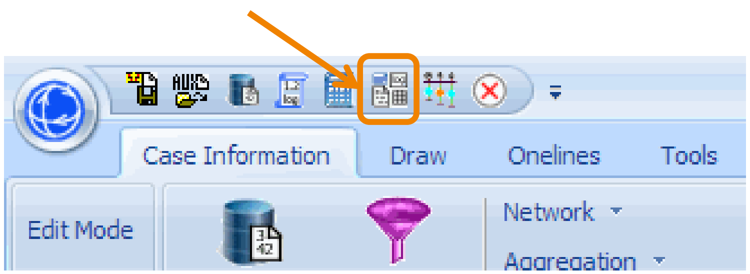


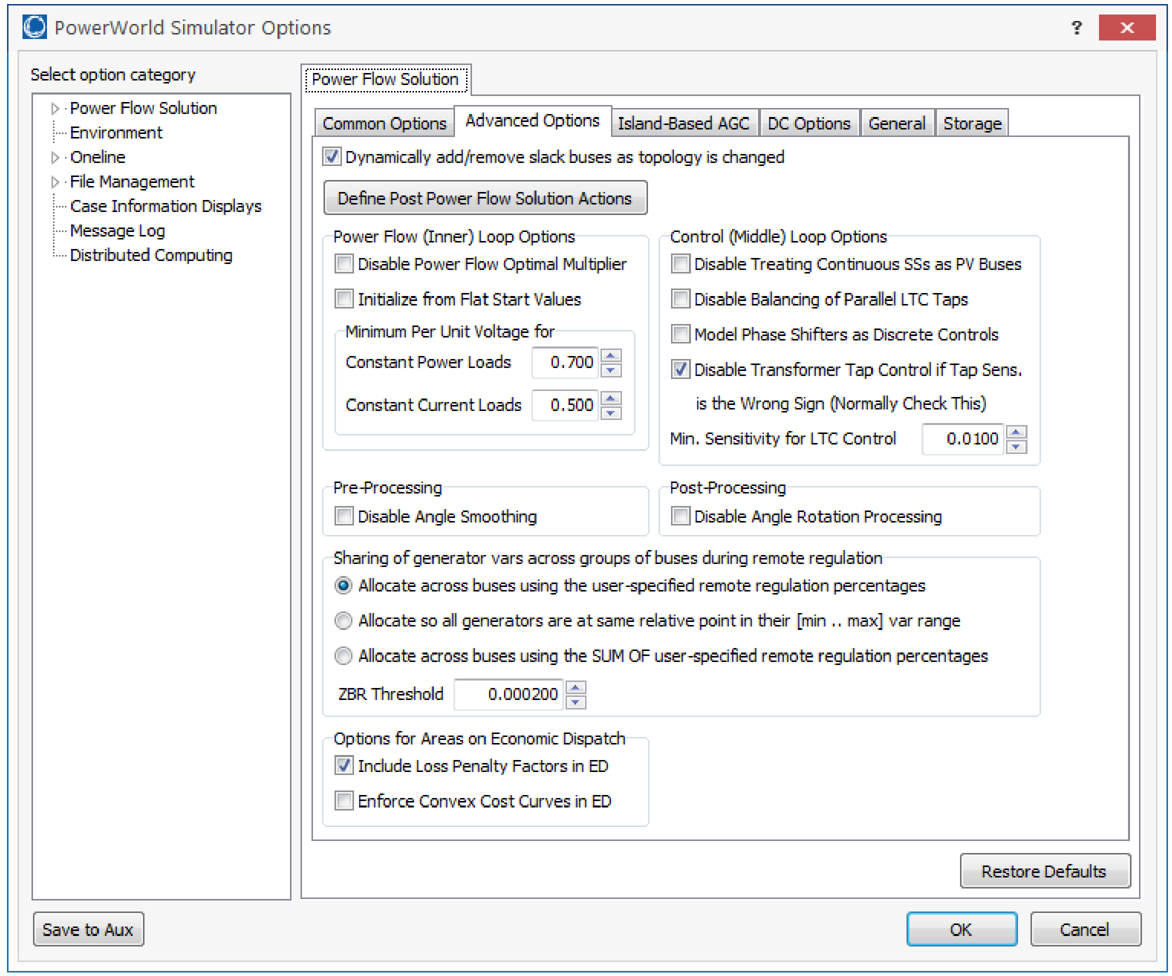
Advanced Options for Power Flow Solution

- To customize the power flow solution, go to the **Options** ribbon tab and select **Simulator Options →Power Flow Solution** page
  - Advanced Options Tab



Also on the Quick Access Toolbar



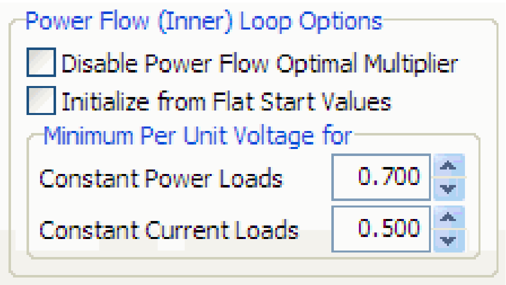


Simulator Options: Power Flow Solution Page

- Advanced Options Tab
  - Dynamically add/remove slack buses as topology is changed (Allow Multiple Islands)
    - If a single island is split into two islands (by opening lines), then a new slack bus is chosen (usually generator with the largest MW limit that regulates its terminal bus)
  - Post Power Flow Solution Actions
    - Allow you to define a list of conditional actions (much like a contingency definition) which occur at the end of *EVERY* power flow solution
    - An example would be loads that are automatically taken out of service when the voltage drops too low

Simulator Options: Power Flow Solution Page

- Advanced Options Tab
  - Disable Power Flow Optimal Multiplier
    - The optimal multiplier is a mathematically calculated step size for Newton's Method that prevents the mismatch equations from increasing between iterations
  - Initialize From Flat Start Values
    - Always starts power flow solution with voltages and angles set to specific values
    - Generator buses or buses regulated by a generator are set to the setpoint voltage of the generator
    - 1.0 per unit for all other buses
    - Angles equal to the slack bus angle (not recommended)
  - Minimum Per Unit Voltage for Constant Power Loads and Constant Current Loads
    - At voltages less than the defined values, the constant power and constant current loads will be reduced
    - To disable either of these features, set the values to 0



Minimum Per Unit Voltage for Constant Power and Current Loads

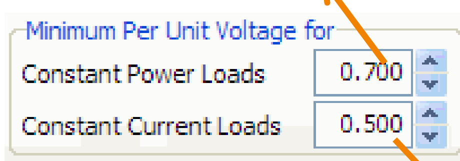
- When a bus voltage is below these thresholds the constant power or current load will gradually decrease to zero MW at zero voltage
  - Constant Power Loads
    - Uses a cosine function
  - Constant Current Loads
    - Uses a sine function multiplied by voltage
- Functions are chosen so that the derivative of the load with respect to voltage is continuous

Minimum Per Unit Voltage for Constant Power and Current Loads

- Minimum Per Unit Voltage for Constant Power

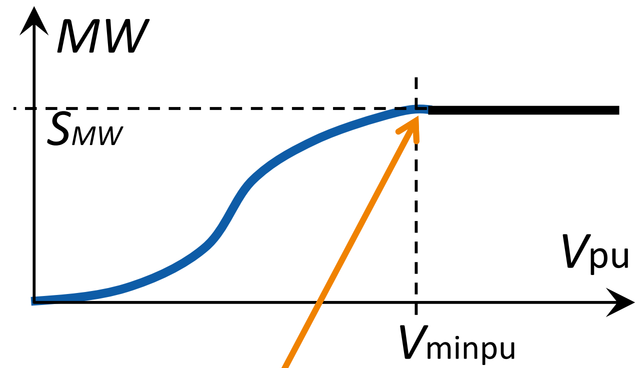
$$MW(V_{pu}) = \frac{S_{MW}}{2}\left(1-\cos\left(\frac{\pi V_{pu}}{V_{S\min pu}}\right)\right)$$

(Default Values are 0.7 and 0.5)

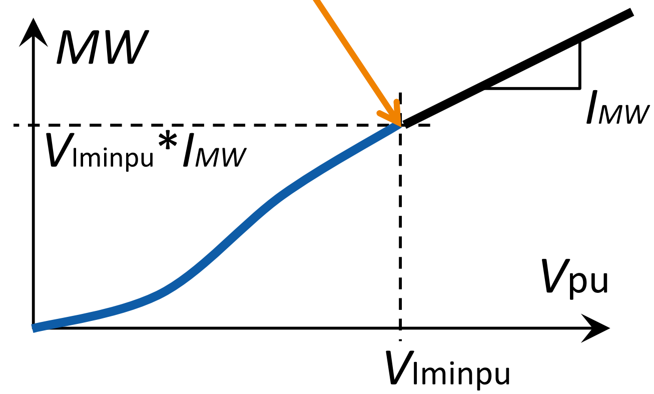


- Minimum Per Unit Voltage for Constant Current

$$MW(V_{pu}) = I_{MW} V_{pu} \sin\left(\frac{\pi}{2}\frac{V_{pu}}{V_{I\min pu}}\right)$$

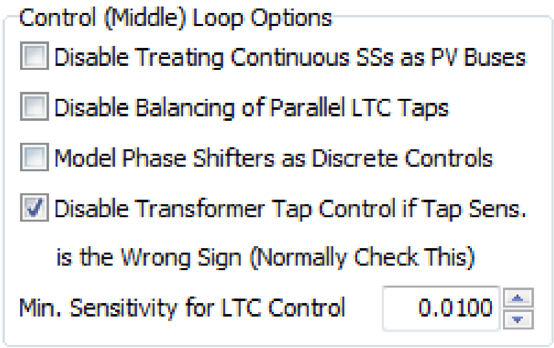


Derivatives with respect to voltage remains continuous at min per unit value



Simulator Options: Power Flow Solution Page

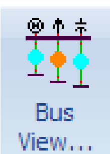
- Advanced Options tab
  - Disable Treating Continuous SSs as PV Buses
    - Continuous switched shunts are normally treated as buses with fixed real power and voltage inside the inner power flow loop
  - Disable Balancing of Parallel LTC taps
    - Parallel LTC taps normally have their tap values synchronized to prevent circulating var flow
  - Model Phase Shifters as Discrete Controls
    - Phase shifters will switch tap positions discretely based on the tap step size
    - Normally users do not model the discrete properties of the phase-shifters. Including this can slow power flow solution.
  - Disable Transformer Tap Control if Tap Sens. is the Wrong Sign (Normally Check This)
    - If a transformer is regulating one of its own terminals, the voltage-to-tap sensitivity should be positive if regulating the from bus and negative if regulating the to bus
    - Sensitivity with the wrong sign indicates an unusual system condition
  - Min. Sensitivity for LTC Control
    - Transformers with a sensitivity lower than this will be disabled



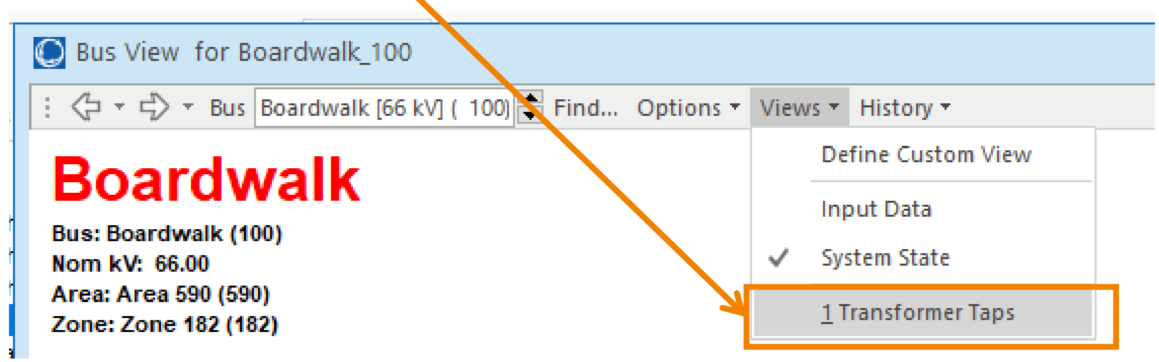
AdvancedOptions.pwb

Example: Parallel Tap Balancing and Minimum Tap Sensitivity

- Choose Open Case
  - *...\S02_AdvancedPowerFlow\AdvancedOptions.pwb*
- Do NOT solve yet
- Open the Bus View



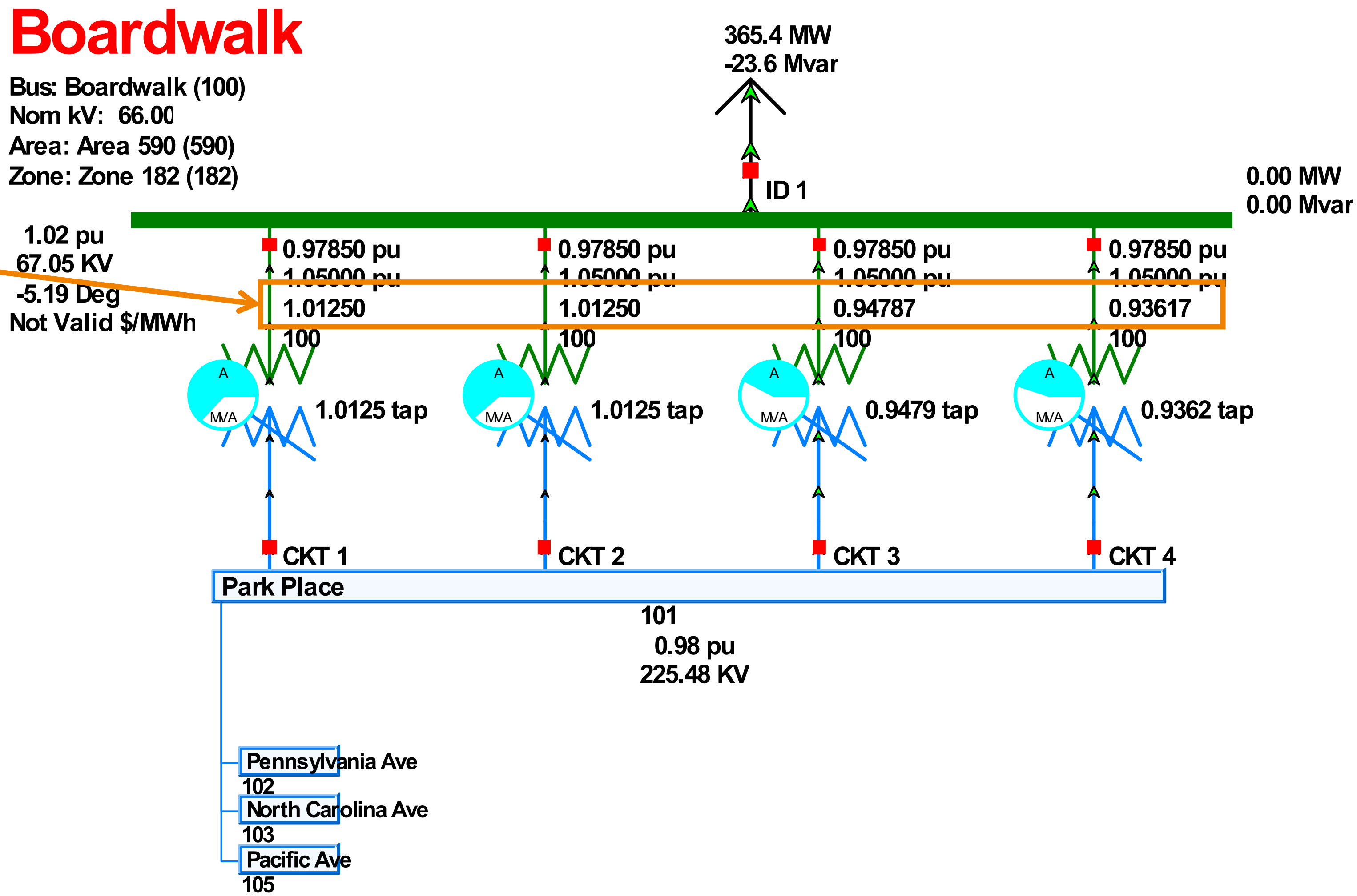
  - Choose **Views > Transformer Taps**
  - This is a Custom View that is already defined



Parallel Tap Balancing

- On Bus View, go to Bus : Boardwalk (100)

Parallel Transformers should have the same tap ratios



Parallel Tap Balancing and Regulation Range Correction

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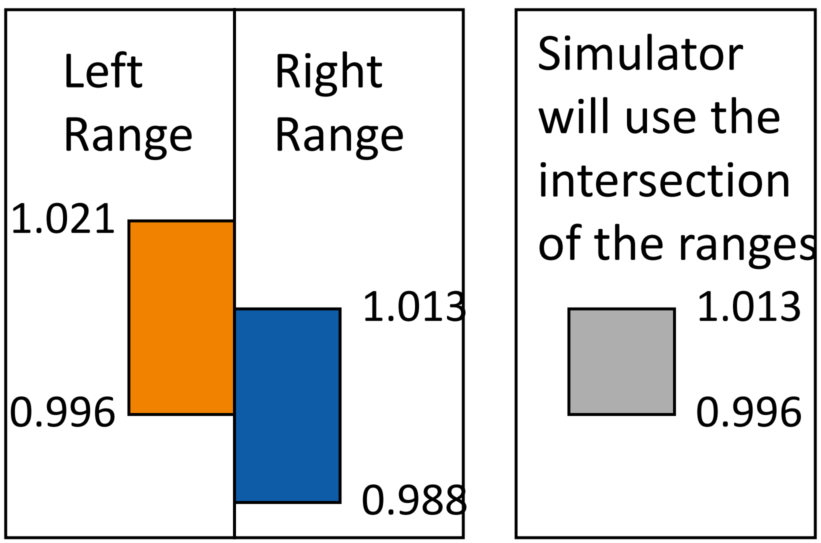
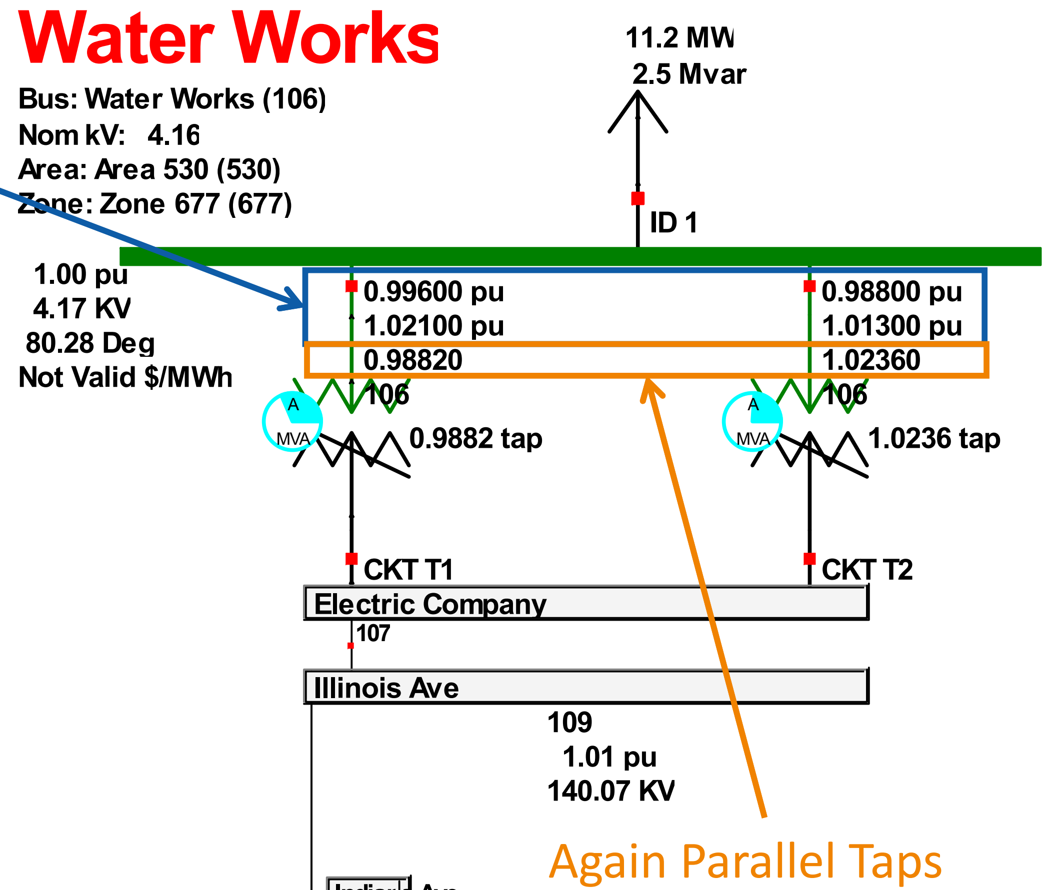
- On Bus View, go to Bus : Water Works (106)

Two Transformers Regulate the same bus (106), but have different regulation ranges





If no intersection, then control turned off

Error: The following parallel transformers have control ranges (Reg Min - Reg Max) which do not overlap.
Transformer 16102 TO 10382 CKT 2 has been turned off control.
Transformer 16102 TO 10382 CKT 1 has been turned off control.

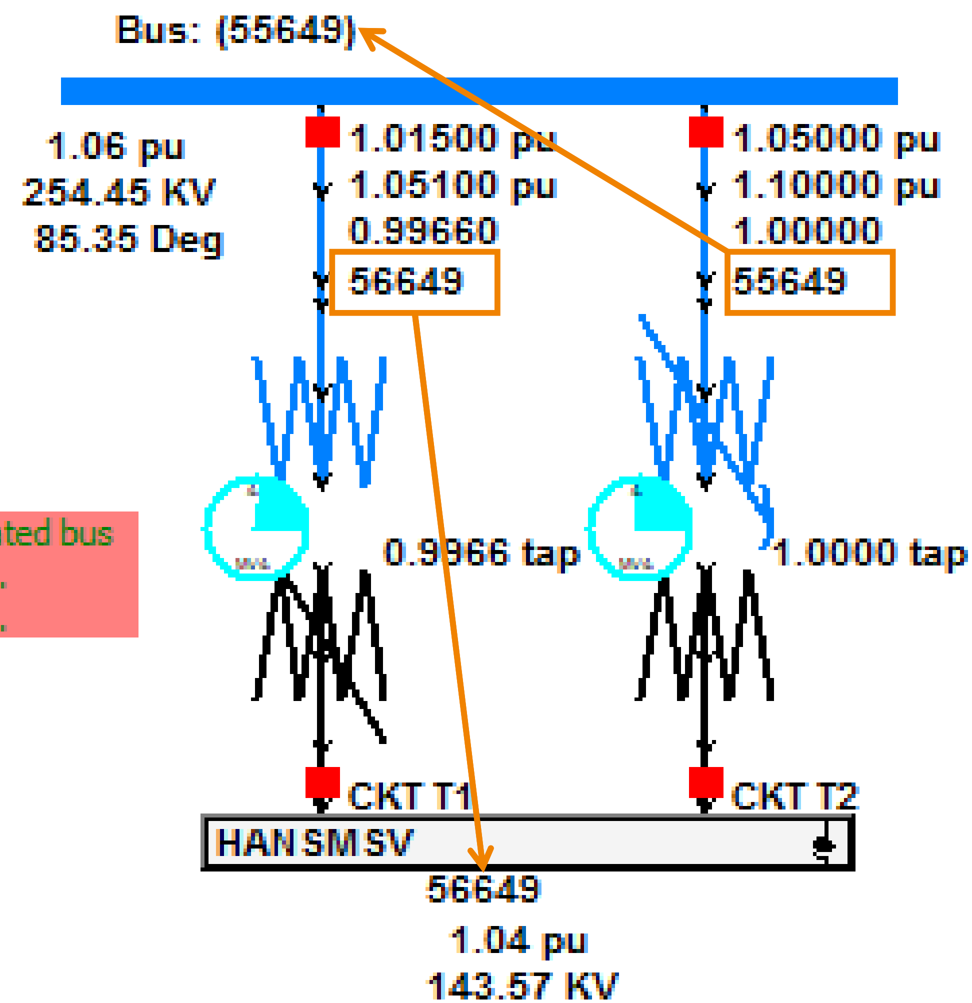
Parallel Taps Regulated Bus Error Checking

Note: Sample case does not have this problem. Slide is just example

- Parallel transformer taps which do not have the same regulated bus
  - Transformer will be turned off control if this occurs
  - Log message will be shown

Error: The following parallel transformers do not share the same regulated bus
Transformer 55649 TO 56649 CKT T2 has been turned off control.
Transformer 56649 TO 55649 CKT T1 has been turned off control.

  - Also allow control if the regulated buses are within the a group of buses connected by very low impedance branches

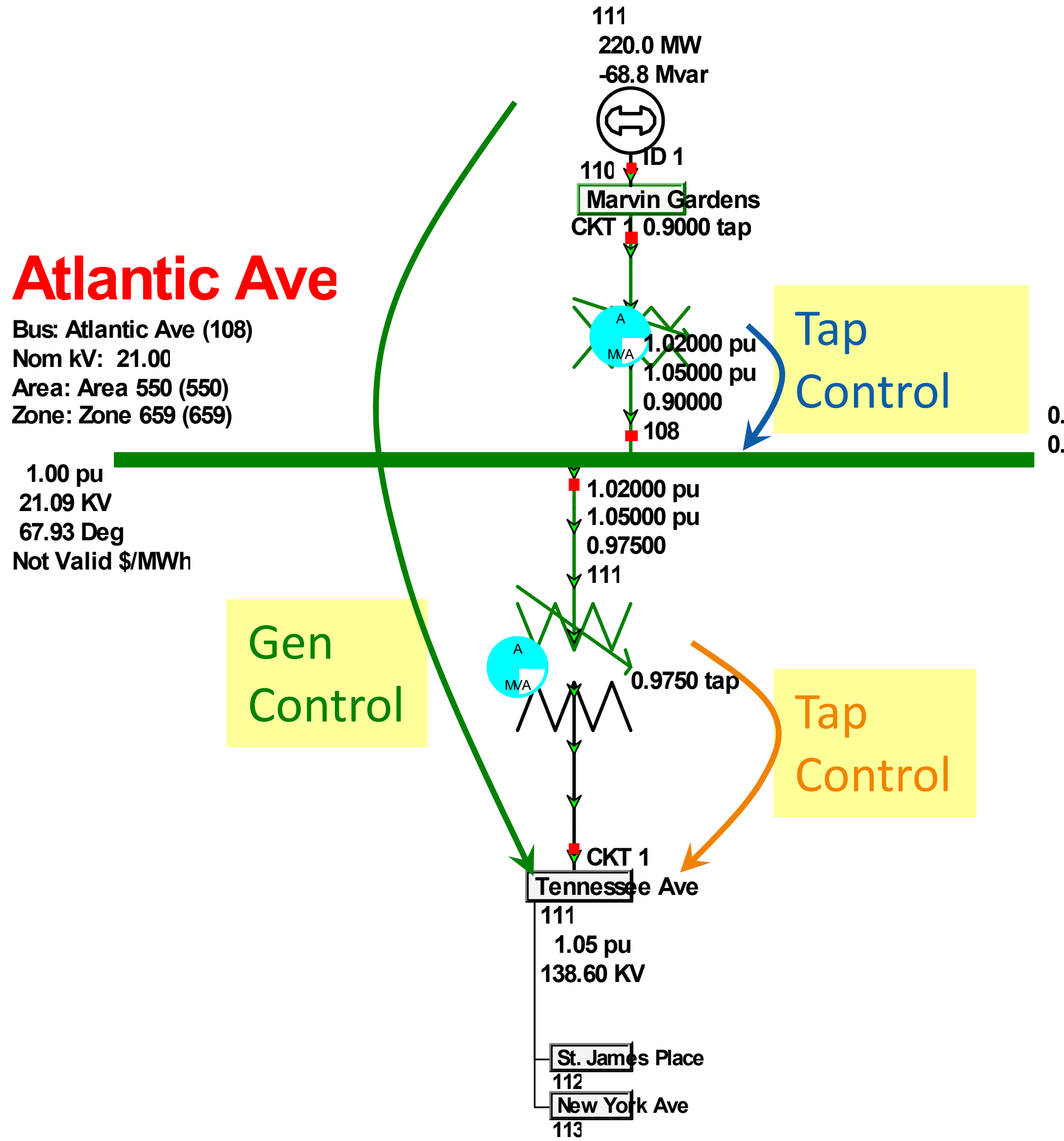


Minimum Tap Sensitivity

- On Bus View, go to Bus : Atlantic Ave (108)

Because the Generator at bus 110 controls the voltage at bus 111, The two transformer taps will not be able to influence their voltages

Taps will only be useful when generator hits its Mvar limits



What Simulator does with these

- Click Single Solution
- Open the Message Log

Starting Solution using Rectangular Newton-Raphson

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Transformer 101 TO 100 CKT 1 tap ratio moved from 1.01250 to 0.96250 to balance with parallel LTCs
Transformer 101 TO 100 CKT 2 tap ratio moved from 1.01250 to 0.96250 to balance with parallel LTCs
Transformer 101 TO 100 CKT 3 tap ratio moved from 0.94787 to 0.97128 to balance with parallel LTCs
Transformer 101 TO 100 CKT 4 tap ratio moved from 0.93617 to 0.96217 to balance with parallel LTCs

Boardwalk

The following parallel transformers have control ranges (Reg Min - Reg Max) that are not the same.
Reg range of 0.99600-1.01300 is being used for all (intersection of the control ranges).
Transformer 107 TO 106 CKT T1 Reg Range specified: 0.99600-1.02100
Transformer 107 TO 106 CKT T2 Reg Range specified: 0.98800-1.01300
Transformer 107 TO 106 CKT T1 tap ratio moved from 0.98820 to 1.00000 to balance with parallel LTCs
Transformer 107 TO 106 CKT T2 tap ratio moved from 1.02360 to 1.00000 to balance with parallel LTCs

Water Works

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Calculating Transformer Tap Sensitivities for 23 Transformers

Transformer 110 TO 108 CKT 1 can not effectively control voltage at bus 108; control will be ignored until the tap sensitivity magnitude increases

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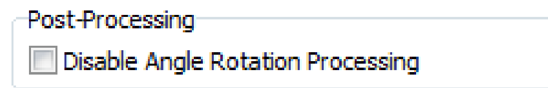
Transformer 108 TO 111 CKT 1 can not effectively control voltage at bus 111; control will be ignored until the tap sensitivity magnitude increases

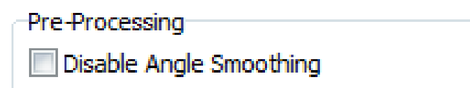
Atlantic Ave

Simulator Options: Power Flow Solution Page

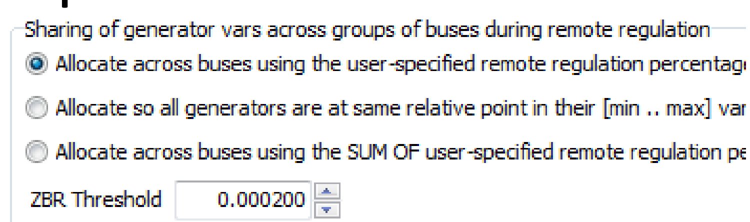
- Advanced Options tab
  - Disable Angle Rotation Processing



    - Voltage angles are rotated so that the angle range in an island is equally spaced around zero degrees if any angles fall outside +/- 160 degrees
  - Disable Angle Smoothing



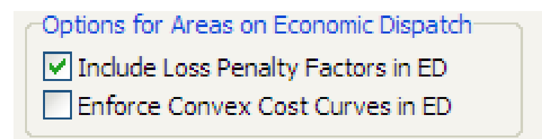
    - Solution difficulties can result if branches are closed with large angle differences across them. Angle smoothing attempts to reconcile these differences prior to the power flow solution.
  - Sharing of generator vars across groups of buses



    - Allocate across buses using the user-specified remote regulation percentages
    - Allocate so all generators are at same relative point in their [min..max] var range
    - Allocate across buses using the SUM OF user-specified remote regulation percentages

Simulator Options: Power Flow Solution Page

- Advanced Options tab
  - ZBR Threshold
    - Determines which buses will be considered the same because they are connected by low impedance branches
    - This affects
      - Generator and switched shunt regulation
      - Parallel transformer tap balancing
      - Voltage pre-processing
  - Options for Areas on Economic Dispatch

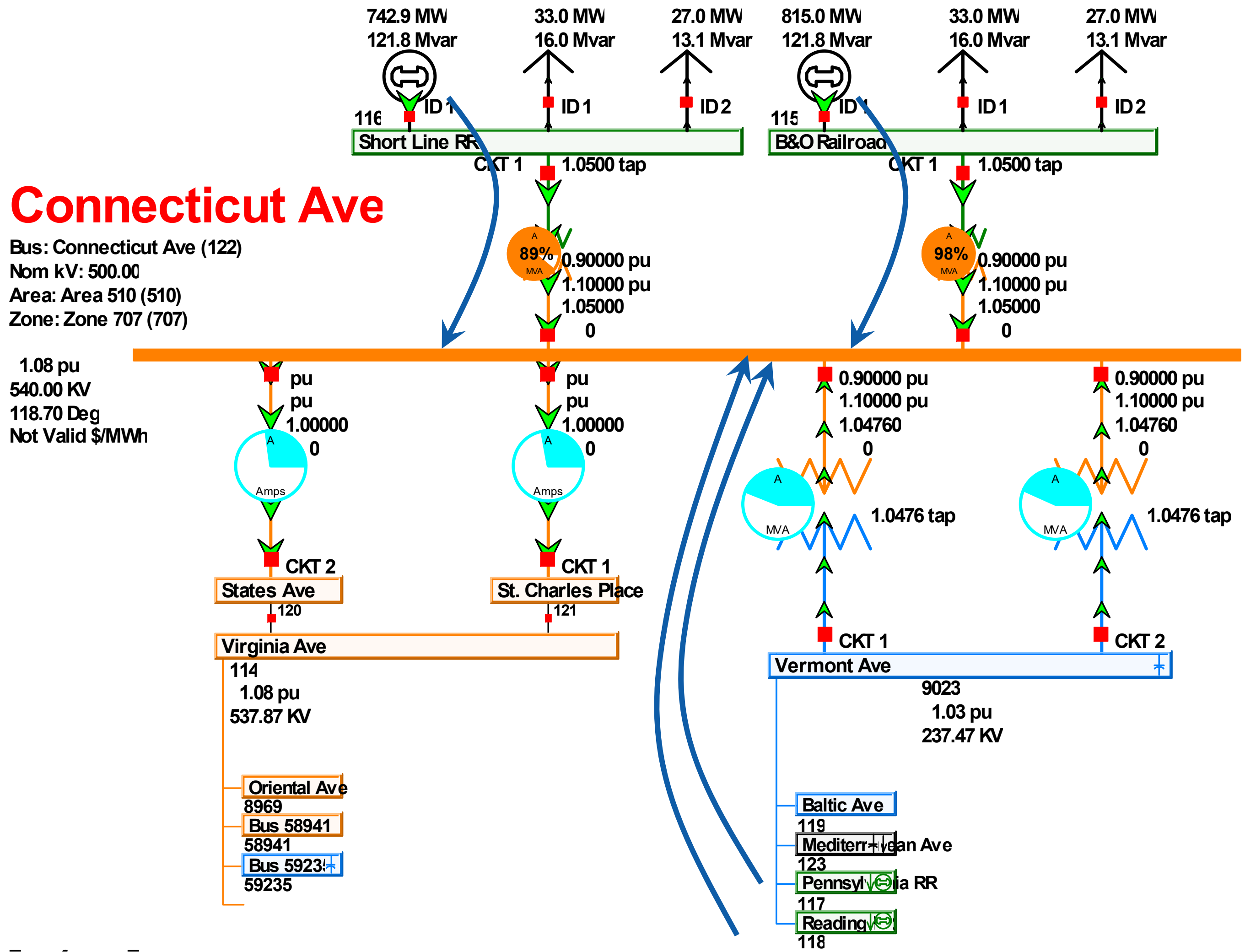


    - Include Loss Penalty Factors in ED will consider losses in determining the dispatch
    - Enforce Convex Cost Curves in ED will turn units that are operating outside the convex portion of their cost curve off automatic control

Sharing of Generator Vars across a group of buses

AdvancedOptions.pwb

- On Bus View, go to Bus : Connecticut Ave (122)
  - Generators at 115, 116, 117, 118 all regulate the voltage at this bus



Var "Responsibility" Sharing

- Go to Model Explorer
  - Navigate to Network → Generators
  - Present setting is to "Allocate across buses using the user-specified remote regulation percentages"

Sharing of generator vars across groups of buses during remote regulation

- (selected) Allocate across buses using the user-specified remote regulation percentages
- Allocate so all generators are at same relative point in their [min .. max] var range
- Allocate across buses using the SUM OF user-specified remote regulation percentages

Generators (Filter:Railroads)

	Number of Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Remote Reg %	Min Mvar	Max Mvar	Set Volt	AVR
1	115	B&O Railroad	1	Closed	815.00	121.78	35.00	-270.70	270.70	1.08000	YES
2	116	Short Line RR	1	Closed	742.88	121.78	35.00	-270.70	270.70	1.08000	YES
3	117	Pennsylvania RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES
4	118	Reading RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES

Sum = 347.96

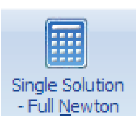
$$0.35 = \frac{121.78}{347.96} \qquad 0.15 = \frac{52.19}{347.96}$$

AdvancedOptions.pwb

Var "Responsibility" Sharing using Remote Reg %

- If you modify the values for *Min Mvar* and *Max Mvar*, the *Gen Mvar* values will not change
  - Change the *Max Mvar* value for generator at bus 115 to 150 Mvar

	Number Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Remote Reg %	Min Mvar	Max Mvar	Set Volt	AVR
1	115	B&O Railroad	1	Closed	815.00	121.78	35.00	-270.70	150.00	1.08000	YES
2	116	Short Line RR	1	Closed	742.88	121.78	35.00	-270.70	270.70	1.08000	YES
3	117	Pennsylvania RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES
4	118	Reading RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES

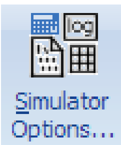


  - Click Single Solution
  - No change in *Gen Mvar* outputs are seen
  - Change the *Max Mvar* value for generator at bus 115 back to 270.7 Mvar

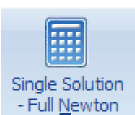
	Number Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Remote Reg %	Min Mvar	Max Mvar	Set Volt	AVR
1	115	B&O Railroad	1	Closed	815.00	121.78	35.00	-270.70	270.70	1.08000	YES
2	116	Short Line RR	1	Closed	742.88	121.78	35.00	-270.70	270.70	1.08000	YES
3	117	Pennsylvania RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES
4	118	Reading RR	1	Closed	330.00	52.19	15.00	-115.00	115.00	1.08000	YES

Var "Responsibility" Sharing using relative [min..max] var range

- Open the Simulator Options Dialog again



  - Go to Power Flow Options, Advanced Options
  - Change to "Allocate so all generators are at same relative point in their [min..max] var range"
  - Click Single Solution



  - Not much change now because the Var Range Ratio is the same as the Remote Reg % values

$$\frac{270.70}{115.00} = \frac{0.35}{0.15}$$

  - To see the different behavior, change *Min Mvar* and *Max Mvar* values

Var "Responsibility" Sharing using relative [min..max] var range

- If you modify the values for *Min Mvar* and *Max Mvar*, the *Gen Mvar* values will change
  - Change the *Max Mvar* value for generator at bus 115 to 150 Mvar

	Number Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Remote Reg %	Min Mvar	Max Mvar	Set Volt	AVR
1	115	B&O Railroad	1	Closed	815.00	61.34	35.00	-270.70	150.00	1.08000	YES
2	116	Short Line RR	1	Closed	742.88	156.60	35.00	-270.70	270.70	1.08000	YES
3	117	Pennsylvania RR	1	Closed	330.00	66.53	15.00	-115.00	115.00	1.08000	YES
4	118	Reading RR	1	Closed	330.00	66.53	15.00	-115.00	115.00	1.08000	YES

  - Click Single Solution
  - *Gen Mvar* outputs change
    - We enforce constant ratio of

$$\frac{\text{GenMvar} - \text{MinMvar}}{\text{MaxMvar} - \text{MinMvar}} = \text{Constant}$$

$$\frac{61.34 - (-270.7)}{150.0 - (-270.7)} = 0.789$$

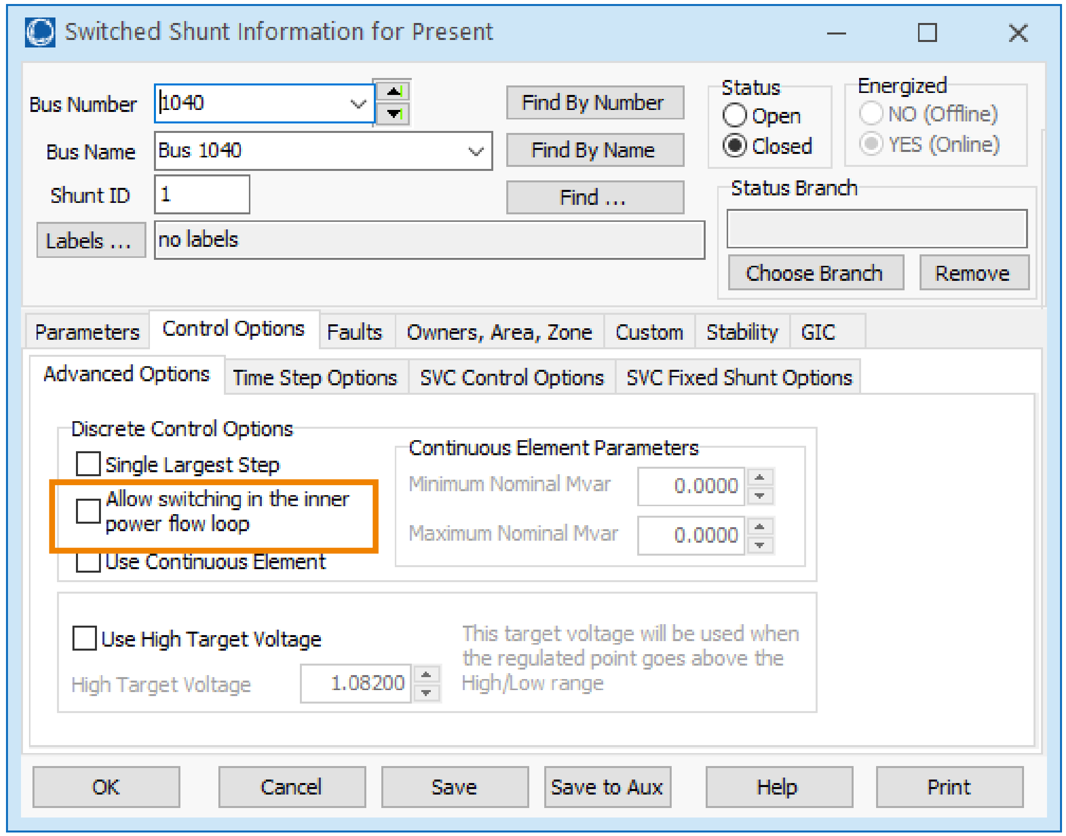
$$\frac{156.6 - (-270.7)}{270.7 - (-270.7)} = 0.789$$

$$\frac{66.53 - (-115.0)}{115.0 - (-115.0)} = 0.789$$

AdvancedOptions.pwb

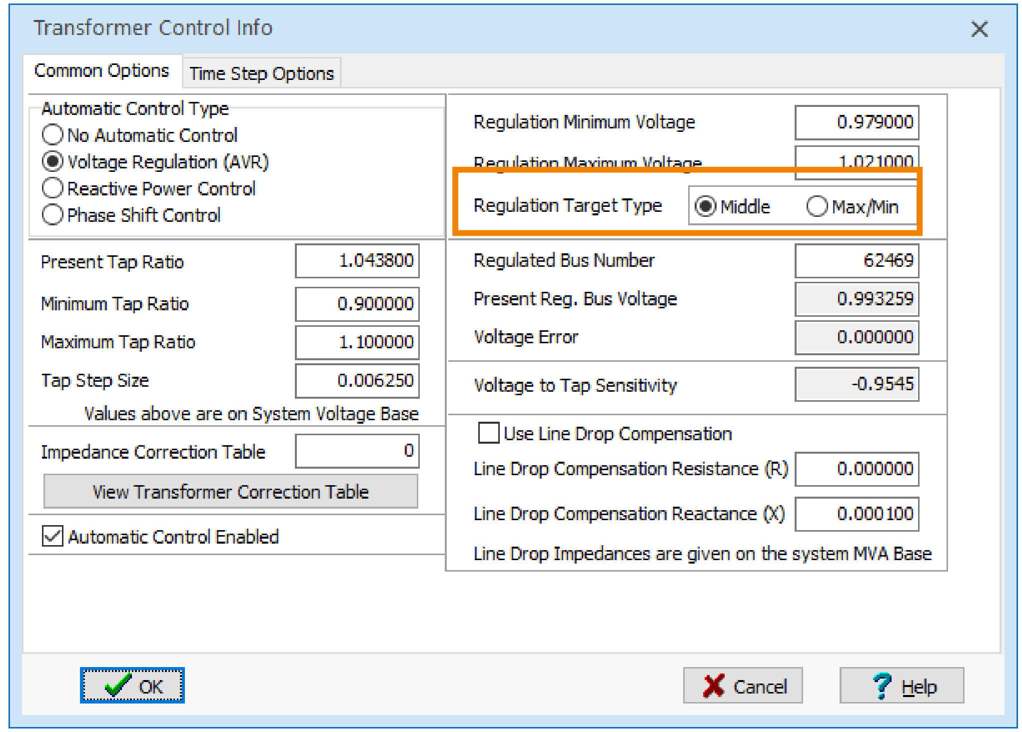
Power Flow Solution: Switched Shunt-Specific Features

- Each Switched Shunt has an option to allow it to switch during the inner power flow loop
  - This allows discrete switched shunts to be treated as PV buses initially and then revert back to discrete shunts after an initial solution
  - Reverting back to discrete shunts is done in Step 1a of the overall power flow solution process. This will cause additional inner power flow loop iterations.



Power Flow Solution: Transformer-Specific Features

- With each transformer, a field called “Regulation Range Target Type” is available
  - Choices are
    - Middle of Reg Range
    - Max/Min of Reg Range
  - Determines what the “target” is for the transformer control when it is not meeting its regulation range



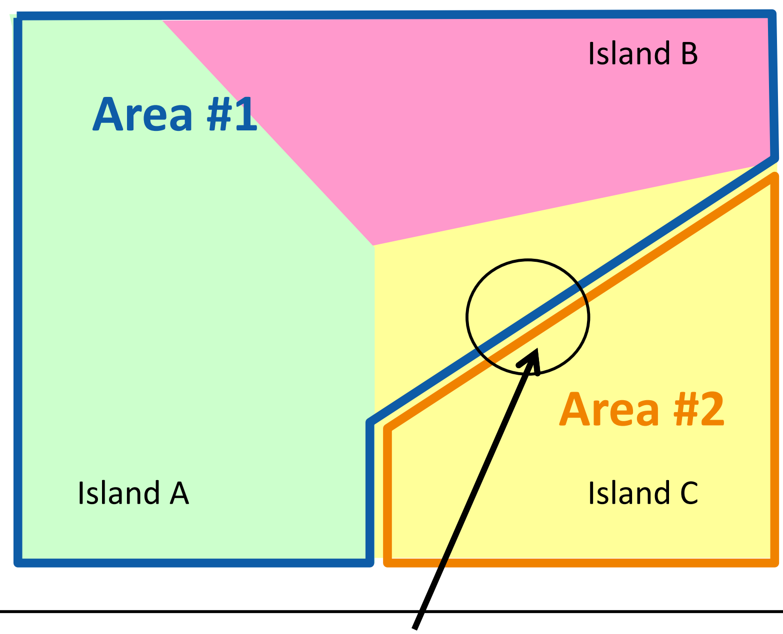
Area Control with Multiple Islands

- When an area spans multiple electric islands, the MW Interchange Control for that area may not be possible
- An error check is done to allow for more complex situations
  - An area that belongs to multiple islands can be placed on control only if at most one of these islands contains multiple areas

Areas Spanning Multiple Islands: Example for Area #1 Control

Control Allowed

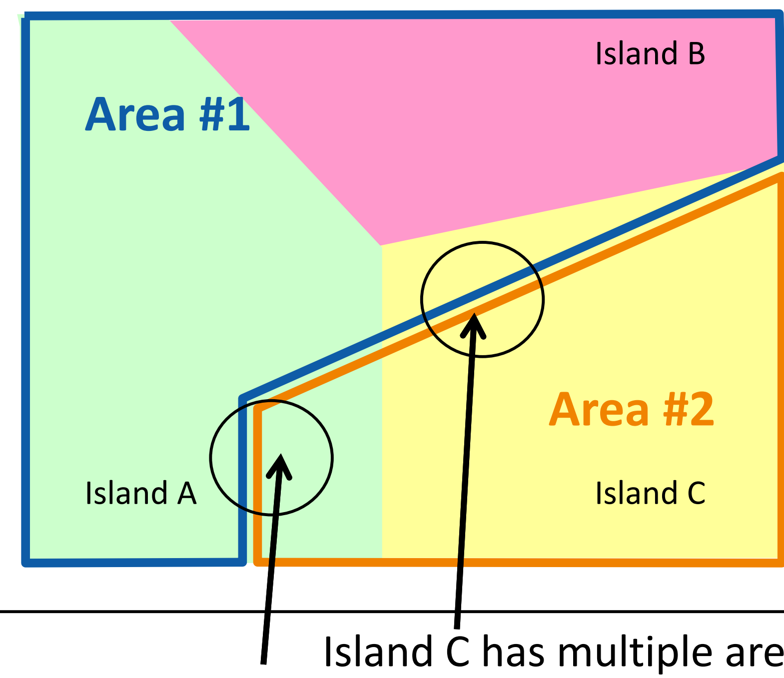
Only Island C has multiple areas



Island C has multiple areas

Control NOT Allowed

Island A and Island C have multiple areas



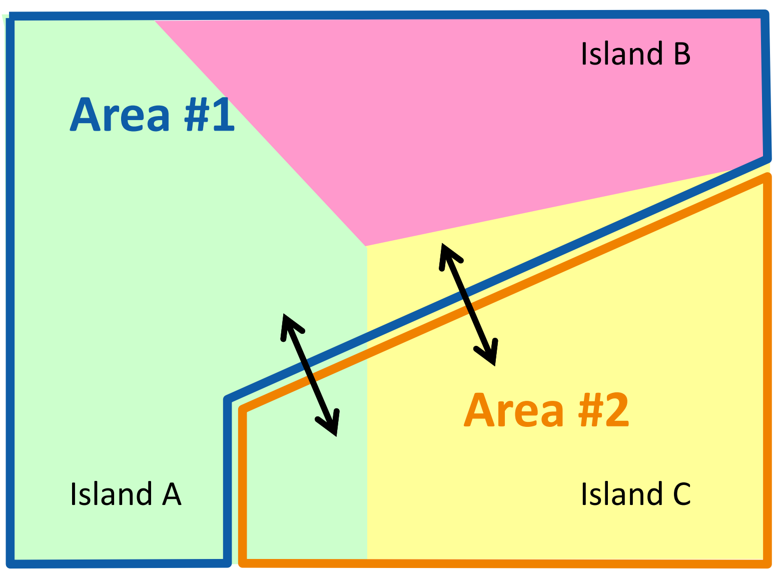
Island C has multiple areas

Island A has multiple areas

This situation occurs for WAPA and ERCOT in Eastern Interconnect cases

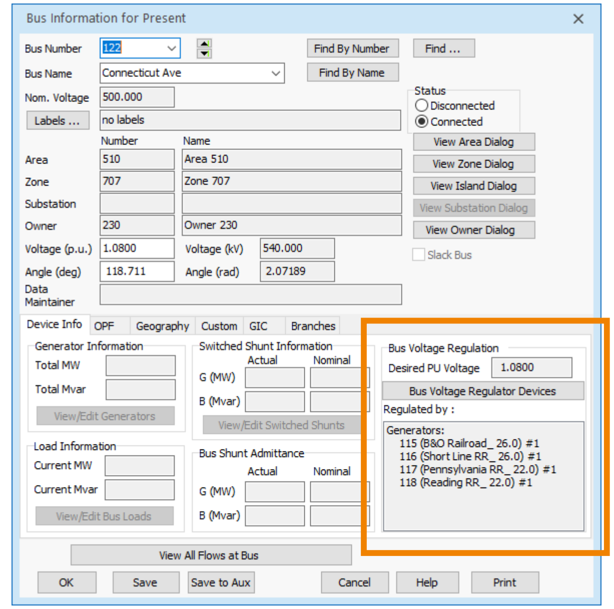
Areas Spanning Multiple Islands : Why control is NOT Allowed

- Not allowed because Simulator doesn't have enough information to know which generators should respond when transactions are specified
  - For example: Area 1 – Area 2 transfer
  - Should transfer occur in Island A or Island C?
    - Because Simulator doesn't know, control is NOT allowed



Power Flow Solution: Solution Diagnosis Aids

- Displays for showing which devices remotely regulate a particular bus are available (generators, LTCs, and shunts)
  - Appears on Run Mode Bus dialog
  - On Model Explorer under **Solution Details\Remotely Regulated Buses** display



Remotely Regulated Buses | Switched Shunts | Generators | Buses

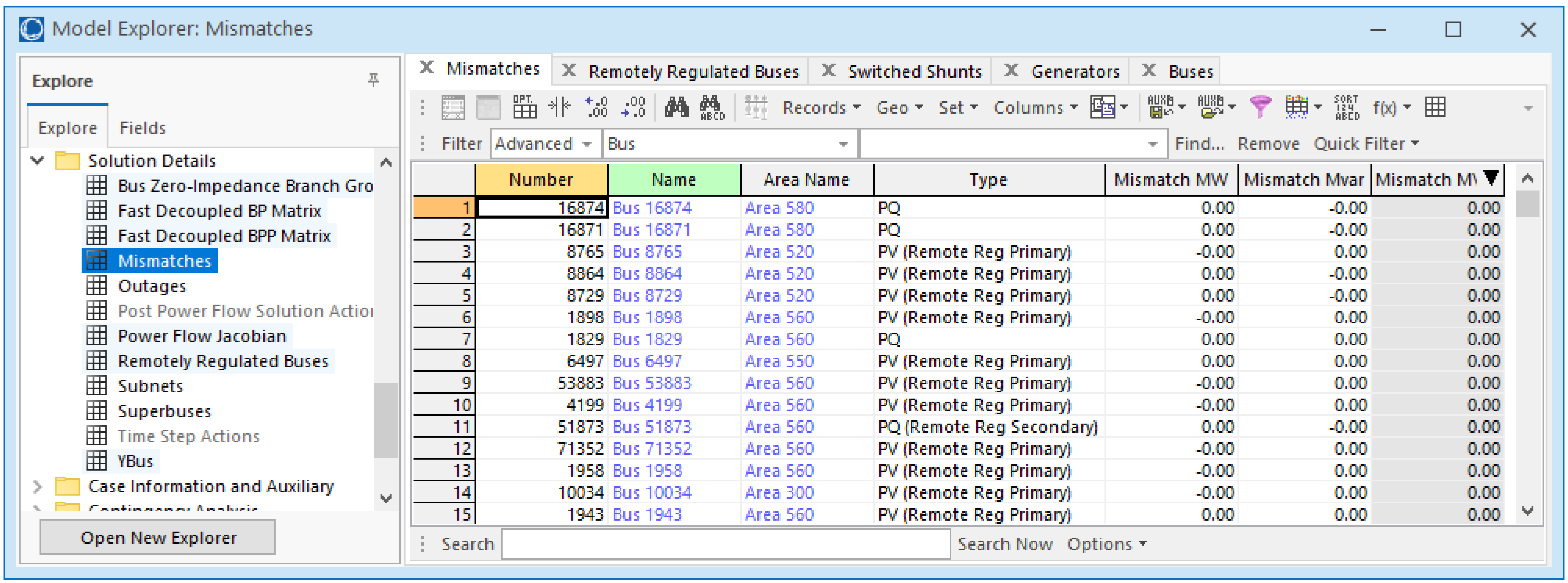
	Number	Name	Area Name	PU Volt	Set Volt	Volt Diff	AVR	Total Mvar	Mvar Min	Mvar Max	Rem Regs (gen)	Rem Regs (XFMR)
1	100	Boardwalk	Area 590	1.01994				0.0	0.0	0.0		LTCs: 101 TO 100 CKT 1, 101 TO 10
2	106	Water Works	Area 530	1.00712				0.0	0.0	0.0		LTCs: 107 TO 106 CKT T1, 107 TO 1
3	108	Atlantic Ave	Area 550	1.00410				0.0	0.0	0.0		LTC: 110 TO 108 CKT 1
4	111	Tennessee Ave	Area 550	1.05000	1.050	0.0000	Yes	-68.8	-87.0	122.0	Generator: 110 #1	LTC: 108 TO 111 CKT 1
5	114	Virginia Ave	Area 510	1.07580				0.0	0.0	0.0		
6	122	Connecticut Ave	Area 510	1.08000	1.080	0.0000	Yes	351.0	-771.4	650.7	Generators: 115 #1, 116 #1, 117 #1, 118 #1	
7	123	Mediterranean Ave	Area 510	1.03004				0.0	0.0	0.0		
8	1025	Bus 1025	Area 560	1.02600	1.026	0.0000	Yes	-7.7	-57.1	37.7	Generator: 21491 #1	
9	1040	Bus 1040	Area 560	1.08486				0.0	0.0	0.0		
10	1058	Bus 1058	Area 560	0.99679				0.0	0.0	0.0		LTC: 51033 TO 1058 CKT 1

Power Flow Solution: Solution Diagnosis Aids

- There is a field for buses called **Solution\Type (PV, PQ, Slack, etc.)**
  - Descriptive strings to better help understand the power flow solution
  - Column is shown by default on **Network\Mismatches** table

Slack, PQ, and PV

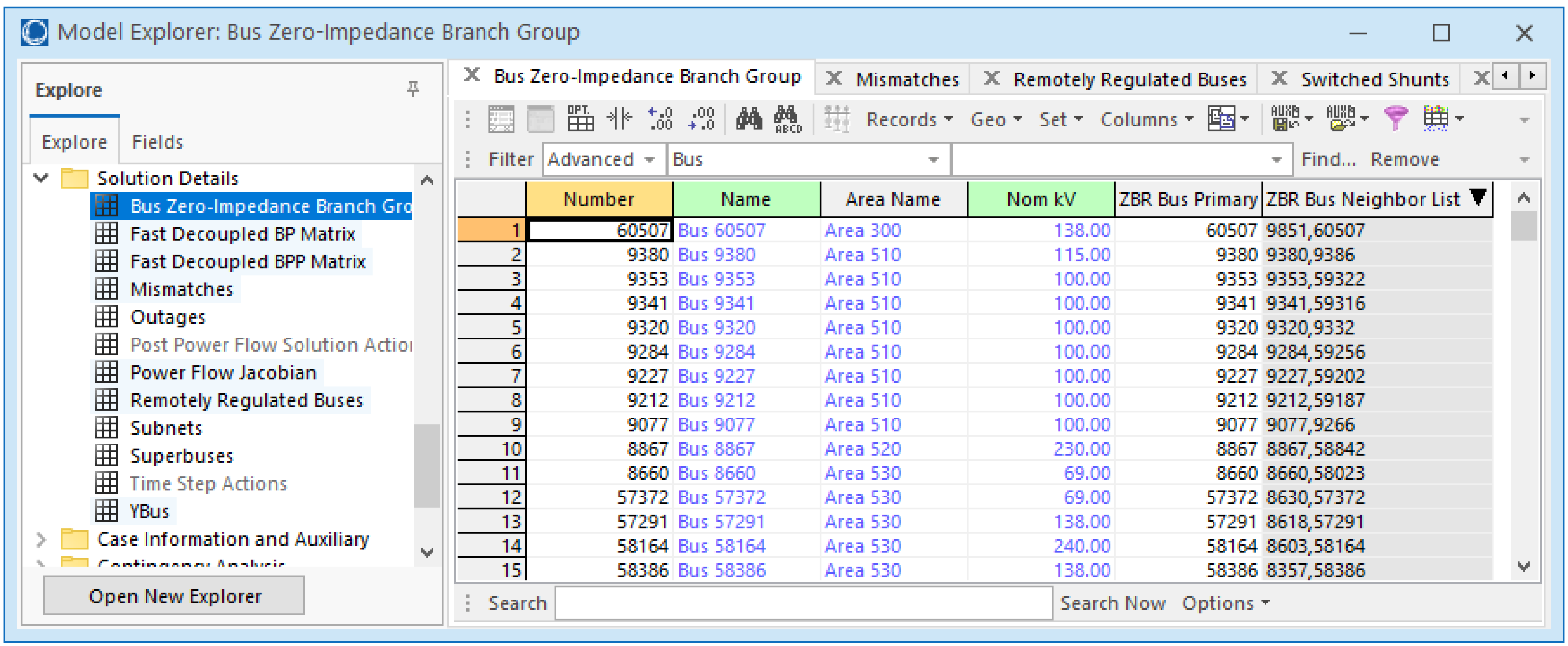
PV (Remote Reg Master)	PQ (Remote Reg Slave)
PQ (Continuous Shunts at Var Limit)	PQ (Gens at Var Limit)
PQ (Remotely Regulated at Var Limit)	PQ (Remotely Regulated)



	Number	Name	Area Name	Type	Mismatch MW	Mismatch Mvar	Mismatch M\
1	16874	Bus 16874	Area 580	PQ	0.00	-0.00	0.00
2	16871	Bus 16871	Area 580	PQ	0.00	-0.00	0.00
3	8765	Bus 8765	Area 520	PV (Remote Reg Primary)	-0.00	0.00	0.00
4	8864	Bus 8864	Area 520	PV (Remote Reg Primary)	0.00	-0.00	0.00
5	8729	Bus 8729	Area 520	PV (Remote Reg Primary)	0.00	-0.00	0.00
6	1898	Bus 1898	Area 560	PV (Remote Reg Primary)	-0.00	0.00	0.00
7	1829	Bus 1829	Area 560	PQ	0.00	0.00	0.00
8	6497	Bus 6497	Area 550	PV (Remote Reg Primary)	0.00	0.00	0.00
9	53883	Bus 53883	Area 560	PV (Remote Reg Primary)	-0.00	0.00	0.00
10	4199	Bus 4199	Area 560	PV (Remote Reg Primary)	-0.00	0.00	0.00
11	51873	Bus 51873	Area 560	PQ (Remote Reg Secondary)	0.00	-0.00	0.00
12	71352	Bus 71352	Area 560	PV (Remote Reg Primary)	-0.00	0.00	0.00
13	1958	Bus 1958	Area 560	PV (Remote Reg Primary)	-0.00	0.00	0.00
14	10034	Bus 10034	Area 300	PV (Remote Reg Primary)	-0.00	0.00	0.00
15	1943	Bus 1943	Area 560	PV (Remote Reg Primary)	0.00	0.00	0.00

Power Flow Solution: Solution Diagnosis Aids

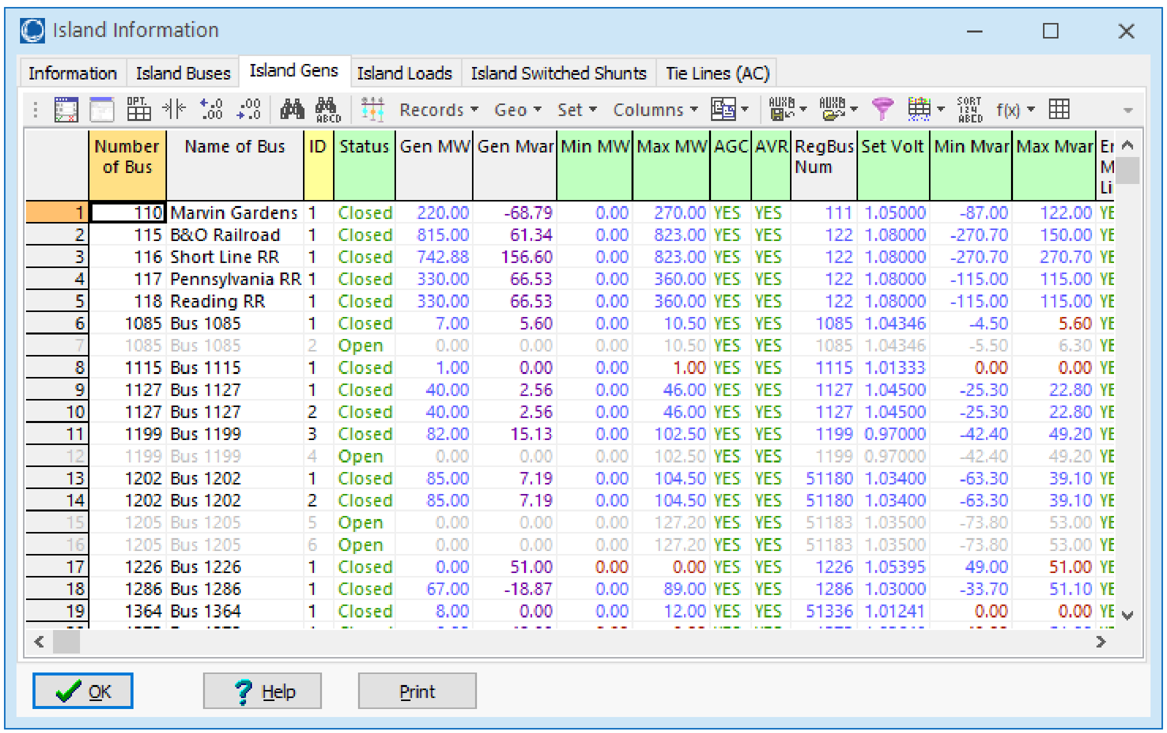
- Bus Zero Impedance branch groupings display
  - Model Explorer under **Solution Details\Bus Zero-Impedance Branch Group**



	Number	Name	Area Name	Nom kV	ZBR Bus Primary	ZBR Bus Neighbor List
1	60507	Bus 60507	Area 300	138.00	60507	9851,60507
2	9380	Bus 9380	Area 510	115.00	9380	9380,9386
3	9353	Bus 9353	Area 510	100.00	9353	9353,59322
4	9341	Bus 9341	Area 510	100.00	9341	9341,59316
5	9320	Bus 9320	Area 510	100.00	9320	9320,9332
6	9284	Bus 9284	Area 510	100.00	9284	9284,59256
7	9227	Bus 9227	Area 510	100.00	9227	9227,59202
8	9212	Bus 9212	Area 510	100.00	9212	9212,59187
9	9077	Bus 9077	Area 510	100.00	9077	9077,9266
10	8867	Bus 8867	Area 520	230.00	8867	8867,58842
11	8660	Bus 8660	Area 530	69.00	8660	8660,58023
12	57372	Bus 57372	Area 530	69.00	57372	8630,57372
13	57291	Bus 57291	Area 530	138.00	57291	8618,57291
14	58164	Bus 58164	Area 530	240.00	58164	8603,58164
15	58386	Bus 58386	Area 530	138.00	58386	8357,58386

Power Flow Solution: Solution Diagnosis Aids

- Island Information dialog lists the buses, generators, loads, and switched shunts that are part of an island



	Number of Bus	Name of Bus	ID	Status	Gen MW	Gen Mvar	Min MW	Max MW	AGC	AVR	RegBus Num	Set Volt	Min Mvar	Max Mvar	Er M Li
1	110	Marvin Gardens	1	Closed	220.00	-68.79	0.00	270.00	YES	YES	111	1.05000	-87.00	122.00	YE
2	115	B&O Railroad	1	Closed	815.00	61.34	0.00	823.00	YES	YES	122	1.08000	-270.70	150.00	YE
3	116	Short Line RR	1	Closed	742.88	156.60	0.00	823.00	YES	YES	122	1.08000	-270.70	270.70	YE
4	117	Pennsylvania RR	1	Closed	330.00	66.53	0.00	360.00	YES	YES	122	1.08000	-115.00	115.00	YE
5	118	Reading RR	1	Closed	330.00	66.53	0.00	360.00	YES	YES	122	1.08000	-115.00	115.00	YE
6	1085	Bus 1085	1	Closed	7.00	5.60	0.00	10.50	YES	YES	1085	1.04346	-4.50	5.60	YE
7	1085	Bus 1085	2	Open	0.00	0.00	0.00	10.50	YES	YES	1085	1.04346	-5.50	6.30	YE
8	1115	Bus 1115	1	Closed	1.00	0.00	0.00	1.00	YES	YES	1115	1.01333	0.00	0.00	YE
9	1127	Bus 1127	1	Closed	40.00	2.56	0.00	46.00	YES	YES	1127	1.04500	-25.30	22.80	YE
10	1127	Bus 1127	2	Closed	40.00	2.56	0.00	46.00	YES	YES	1127	1.04500	-25.30	22.80	YE
11	1199	Bus 1199	3	Closed	82.00	15.13	0.00	102.50	YES	YES	1199	0.97000	-42.40	49.20	YE
12	1199	Bus 1199	4	Open	0.00	0.00	0.00	102.50	YES	YES	1199	0.97000	-42.40	49.20	YE
13	1202	Bus 1202	1	Closed	85.00	7.19	0.00	104.50	YES	YES	51180	1.03400	-63.30	39.10	YE
14	1202	Bus 1202	2	Closed	85.00	7.19	0.00	104.50	YES	YES	51180	1.03400	-63.30	39.10	YE
15	1205	Bus 1205	5	Open	0.00	0.00	0.00	127.20	YES	YES	51183	1.03500	-73.80	53.00	YE
16	1205	Bus 1205	6	Open	0.00	0.00	0.00	127.20	YES	YES	51183	1.03500	-73.80	53.00	YE
17	1226	Bus 1226	1	Closed	0.00	51.00	0.00	0.00	YES	YES	1226	1.05395	49.00	51.00	YE
18	1286	Bus 1286	1	Closed	67.00	-18.87	0.00	89.00	YES	YES	1286	1.03000	-33.70	51.10	YE
19	1364	Bus 1364	1	Closed	8.00	0.00	0.00	12.00	YES	YES	51336	1.01241	0.00	0.00	YE