# Power Flow Analysis and Voltage Control using Simulator

- Formulation of the power flow problem
- Newton's method for solving the power flow
- Description of the **PowerWorld Simulator Options** Dialog accessed from the **Options** ribbon tab, **Simulator Options** button.
- Explanation of voltage-related controls
  - generator AVR
  - transformer taps
  - switched shunts

# Overall Simulator Solution Methodology

- Simulator actually uses *THREE* nested loops to solve the power flow
- MW Control Loop
  - Voltage Controller Loop
    - Inner Power Flow loop

Traditionally called the *Power Flow Solution*

Voltage Control Loop also covered in this section

MW Control Loop also covered later

# Formulation of Power Flow: "Inner Power Flow Loop"

- Goal is to solve the nonlinear power balance equations for all system buses
- For an n bus power system

$I = Y_{bus} V$

where

$I$ = complex vector of current injection at all buses

$V$ = complex vector of voltage at all buses

$Y_{bus}$ = complex n by n bus admittance matrix

# Nonlinear Power Flow Equations

- Complex nonlinear power balance equations

  $S^* = V^* I$

  $S^* = V^* Y_{bus} V$

- Convert to 2(n-1) real equations

  $S = g(x)$ or $f(x) = 0$

  where

  S = 2(n-1) power injections

  x = 2(n-1) voltage magnitudes and angles

# Slack and PV Buses

- Exactly one bus in each electrical island is designated as a slack bus
  - provides an angle and voltage reference
  - must be a bus with a generator
  - voltage angle and magnitude fixed
  - real/reactive output of generator free to vary
    - Simulator tries maintain them within limits, but if that is not possible, this generator will violate limits
- At AVR generator buses (PV buses)
  - voltage magnitude is fixed
  - reactive output of generator is free to vary
- At other buses (PQ buses)
  - Power and Reactive power injections are fixed

# Solving the Power Flow Equations

- Nonlinear equations must be solved iteratively
- There are a number of common solution methods
  - Newton's Method
    - Simulator uses an enhanced Newton's method algorithm
  - Fast Decoupled
    - an option in Simulator
  - Gauss-Seidel
    - presently not available in Simulator

# Newton's Method

Guess initial value of voltages $x^0$, k = 0

Repeat

While ( $|f(x^k)| > \varepsilon$ ) and ($k < k^{max}$) Do

$$x^{k+1} = x^k - [J(x^k)]^{-1} f(x^k)$$

$$k = k + 1$$

End While

Until (no more automatic control changes)

# Newton's Method

Where

| | | |
|---|---|---|
| $k$ | = | Iteration count |
| $k^{max}$ | = | Maximum number of iterations |
| $x^k$ | = | Voltages at the $k^{th}$ iteration |
| $f(x^k)$ | = | Mismatch equations |
| $\varepsilon$ | = | Convergence tolerance (in MVA) |
| $J(x^k)$ | = | Jacobian matrix |

# Seven Bus Example

- Open case B7FLAT.PWB, switch into Run Mode and make sure Message Log visible.
- To view initial mismatches, go to the **Case Information** ribbon tab and select **Model Explorer**. In the **Network** category select **Mismatches**. All mismatches are initially less than 0.1 MVA.
- Open line from bus 2 to bus 5; refresh the mismatches. There are now large values at buses 2 and 5. Solve the case.

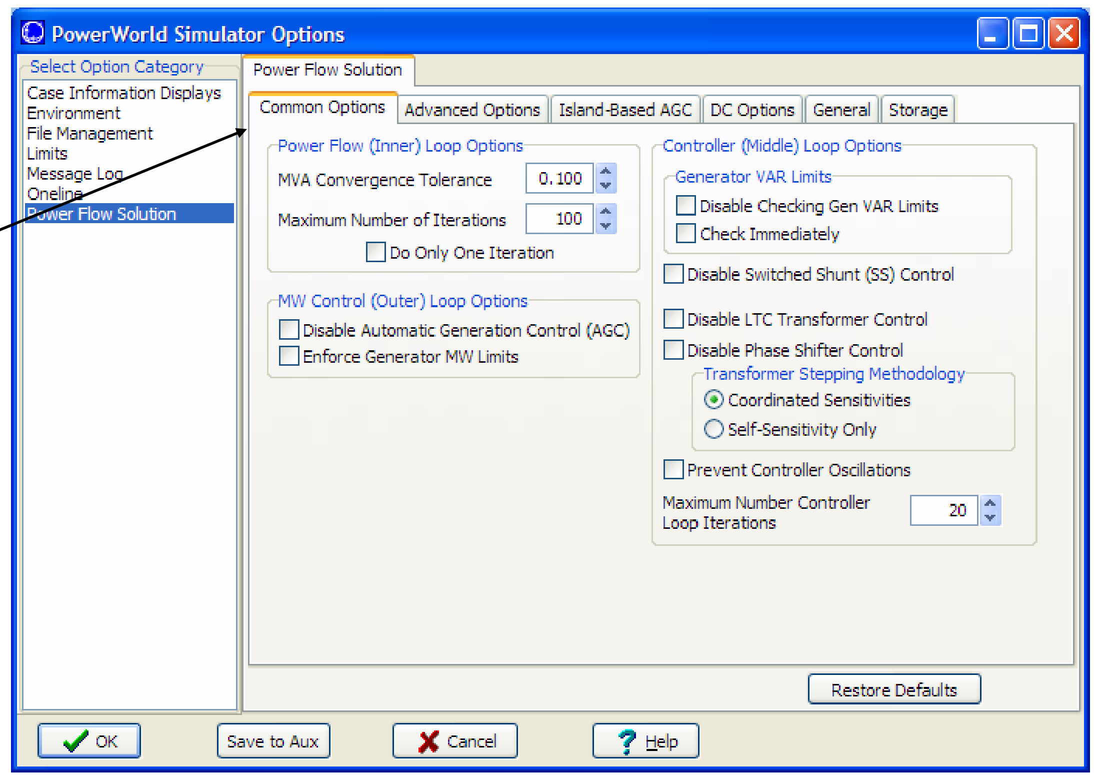
# Power Flow Solution

- Go to the **Tools** ribbon tab and select **Single Solution** to resolve the power flow equations.
- Refresh the mismatch display; notice that mismatches are again less than 0.1 MVA.
- Notice that voltage magnitude has remained fixed at the generator buses. This is because they are being modeled as PV buses.

# Simulator Options: Power Flow Solution Page

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

This will open to the Common Options tab by default



# Simulator Options: Power Flow Solution Page

- Common Options Tab
  - MVA Convergence Tolerance
    - the tolerance for the inner power flow loop
    - Must be larger than zero
  - Maximum Number of Iterations
    - the maximum iterations for the inner power flow loop
  - Do only one iteration
    - Same as setting Maximum Number of Iterations to 1.
  - Disable Automatic Generation Control (AGC) disables enforcement of MW interchange for entire case.

# Simulator Options: Power Flow Solution Page

- Common Options Tab
  - Unchecking Enforce Generator MW Limits means generator MW limits are not enforced
  - Gen MVAR Limits
    - Disable Checking means generator MVAR limits are not enforced
    - Check immediately means the MVAR limits are checked and handled first before a solution iteration is run

# Simulator Options: Power Flow Solution Page

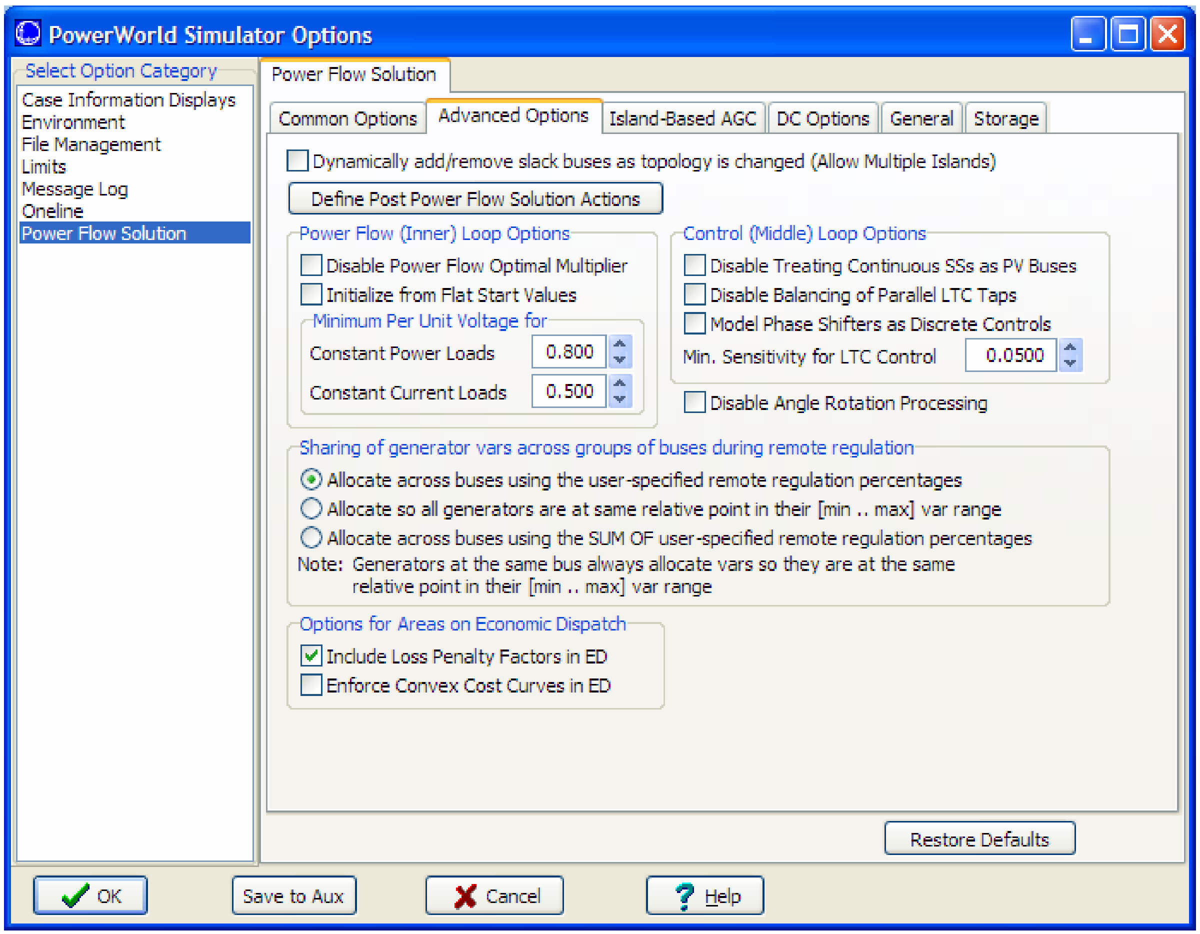
- Common Options Tab
  - Disable Switched Shunt Control (affects entire case)
  - Disable LTC Transformer Control (affects entire case)
  - Disable Phase Shifter Control (affects entire case)
  - Transformer Stepping Methodology
    - Coordinated Sensitivities looks at all transformers that are out-of-range and coordinates the movement to bring all back within regulation range
    - Self-Sensitivity Only looks at each transformer individually and determines the sensitivity of its regulated value with respect to changing its own tap or phase only

# Simulator Options: Power Flow Solution Page

- Common Options Tab
  - Prevent Controller Oscillations
    - keeps controlled devices from continually switching between two control states for the entire case
  - Maximum Number of Controller Loop Iterations
    - The voltage control loop will be limited to this many iterations

# Simulator Options: Power Flow Solution Page

- Advanced Options Tab



# Simulator Options: Power Flow Solution Page

- Advanced Options Tab
  - Dynamically add/remove slack buses as topology is changes (Allow Multiple Islands)
    - If a single island is split into two islands (by opening lines), then a new slack bus is chosen (generator with the largest MW limit is chosen)
  - 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 solutions with voltages at 1.0 per unit and 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

# 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 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
  - Min. Sensitivity for LTC Control
    - Transformers with a sensitivity lower than this will be disabled.

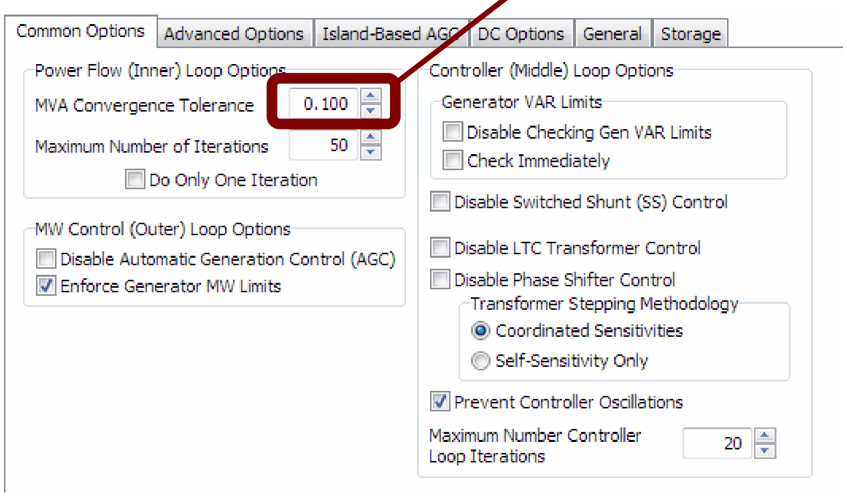
# Simulator Options: Power Flow Solution Page

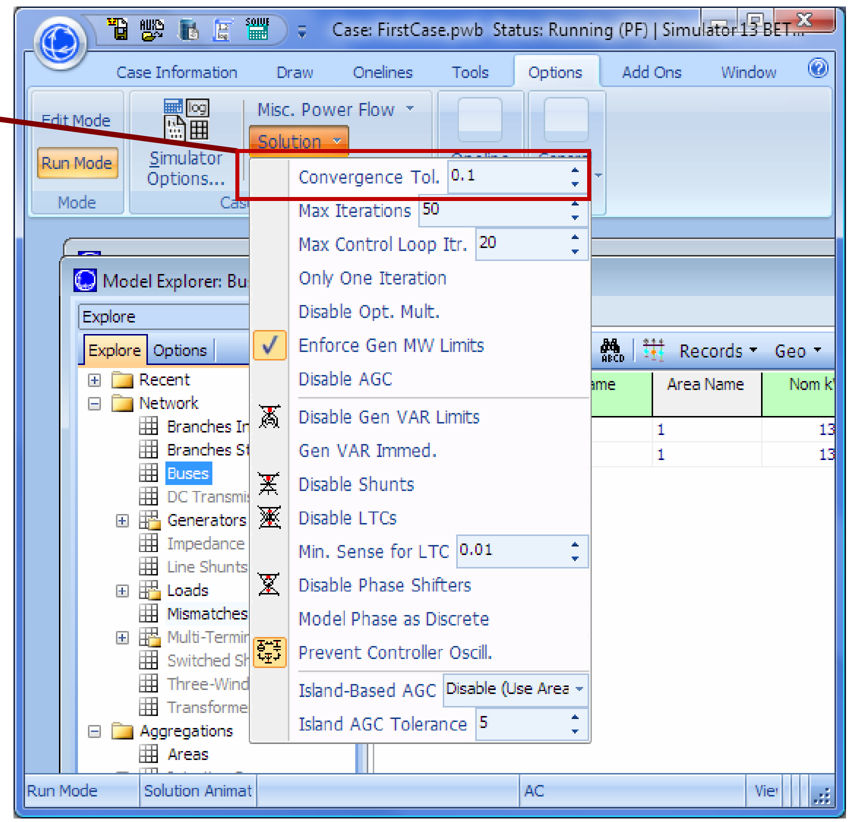
- Advanced Options Tab
  - Disable Angle Rotation Processing
    - Voltage angles are rotated so that the angle range in an island is equally spaced around zero degrees if any angles fall outside +/- 160 degrees
  - Sharing of generator vars across groups of buses
    - Allocate across buses using the 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
  - 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

# Solution Options Toolbar

- Select the **Solution** button on the **Case Options** ribbon group. Note that most of the settings on the dialog are available.

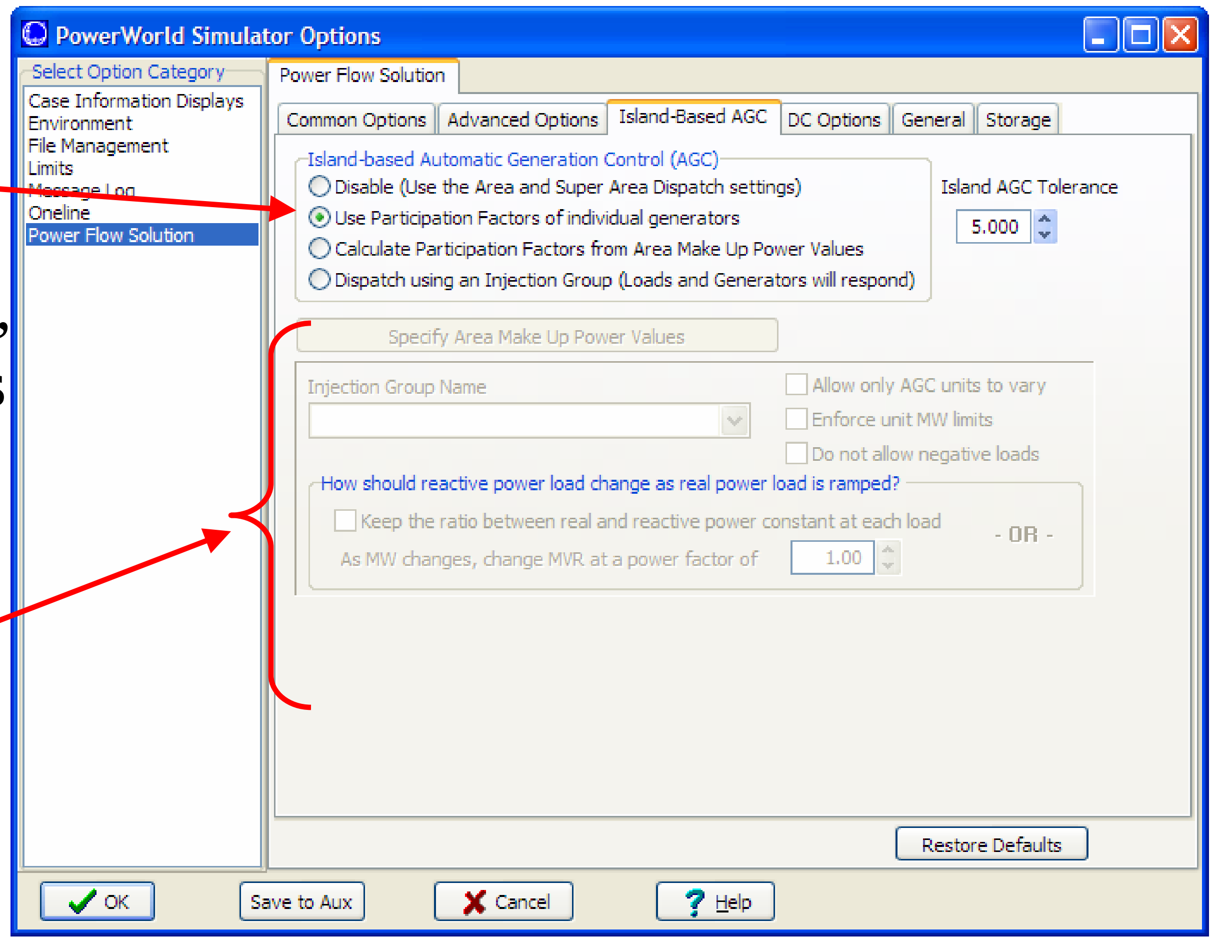
**Same Setting**



# Simulator Options: Power Flow Solution Page

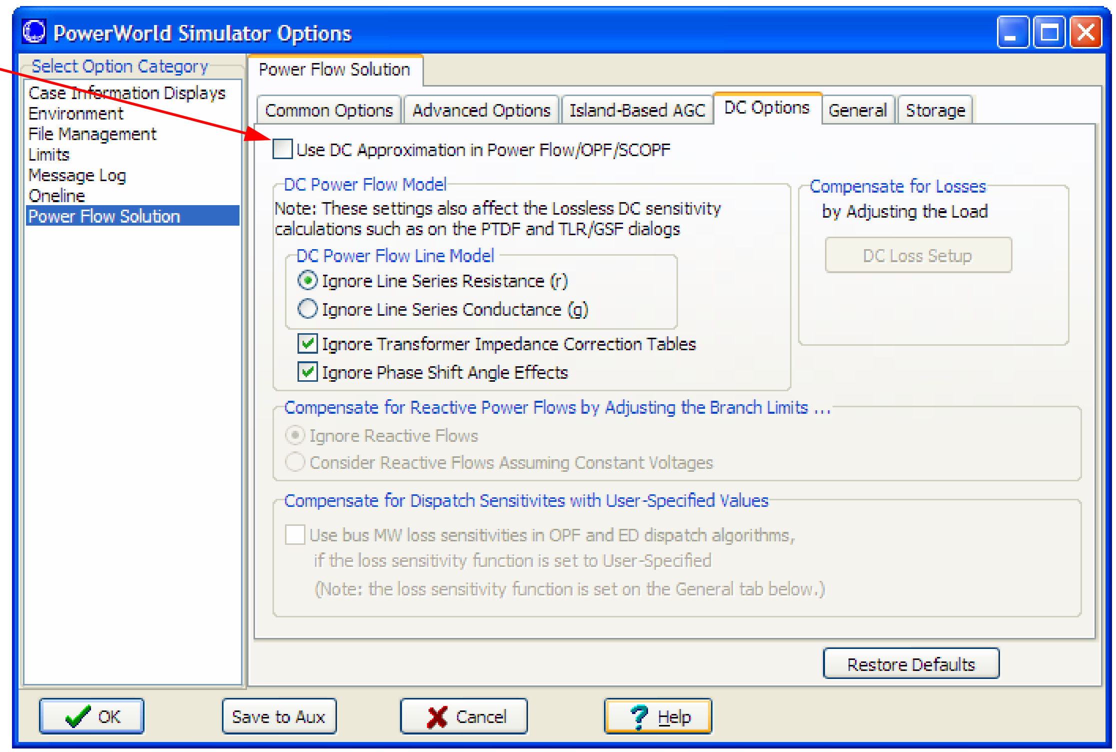
- Island-Based AGC Tab
  - Allow load and generation balancing across an island, instead of Areas or Super Areas




Options used for Injection Group Dispatch

# Simulator Options: Power Flow Solution Page

- DC Options Tab
  - Use DC Approx. in Power Flow / OPF / SCOPF
    - Check this box to model the system using a DC power flow.




Note: Once you convert a large system to a DC power flow, it is very difficult to get the AC system to resolve.

# Simulator Options: Power Flow Solution Page

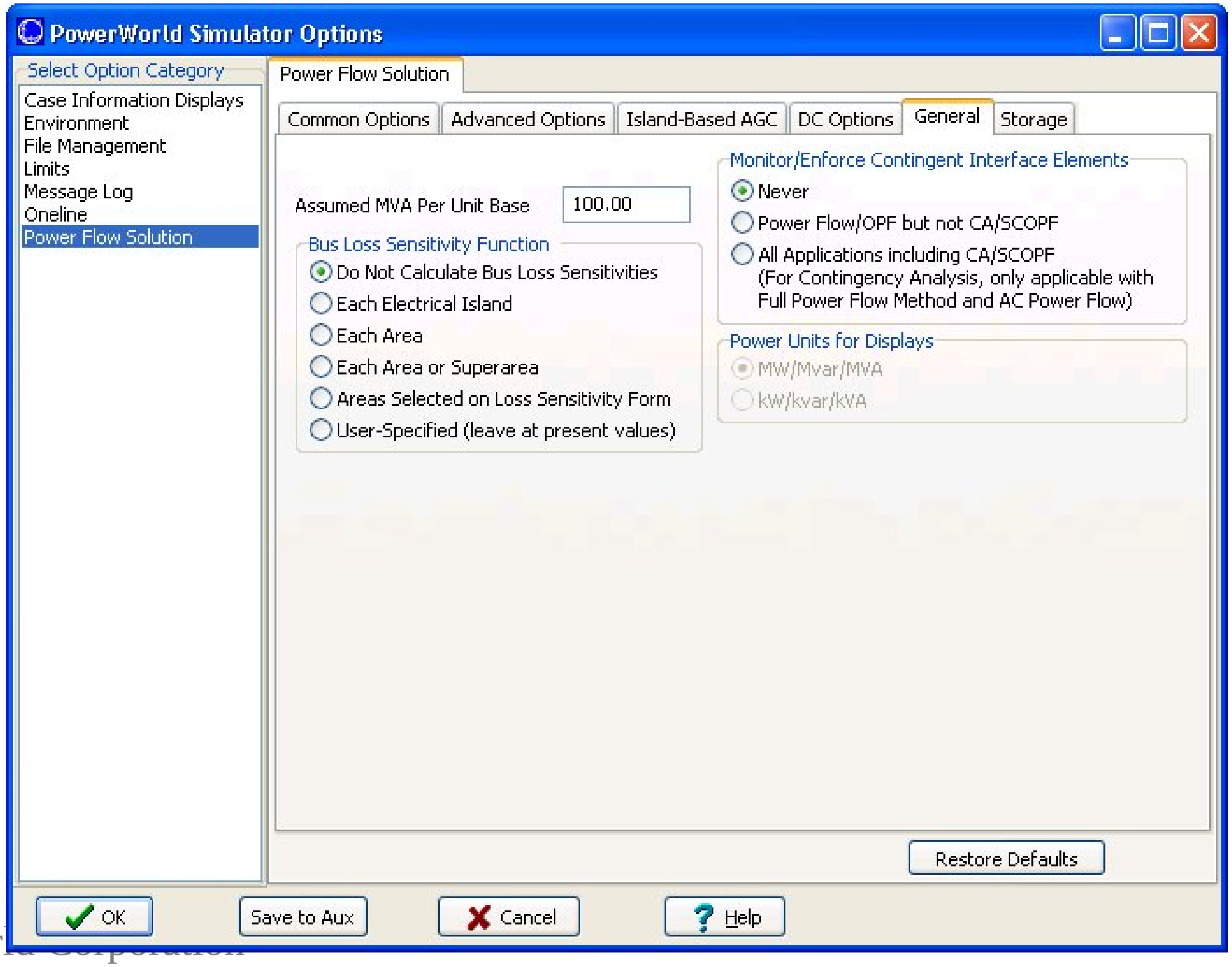
- DC Options Tab
  - Compensate for Losses by Adjusting the Load
    - Specify a load multiplier at each bus. When solving the DC power, Simulator will artificially increase loads by this multiplier
  - Compensate for Reactive Power Flows by Adjusting the Branch Limits
  - Compensate for Dispatch Sensitivities with User-Specified Values
    - Allows you to make use of loss sensitivities even in the DC power flow

# Simulator Options: Power Flow Solution Page

- DC Options Tab
  - DC Power Flow Model
    - Ignore Line Series Resistance (r)
      - $b = -1/x$, $g = 0$
    - Ignore Line Series Conductance (g)
      - $b = -x/(r^2+x^2)$, $g = 0$
    - Ignore Transformer Impedance Correction Tables and Ignore Phase Shift Angle Effects (default is to ignore)
      - Impedance correction tends to increase impedance and phase shift effects tend to decrease impedance
      - By not ignoring, DC equations become a function of the system state and removes some of the advantages of the DC approximation

# Simulator Options: Power Flow Solution Page

- General Tab

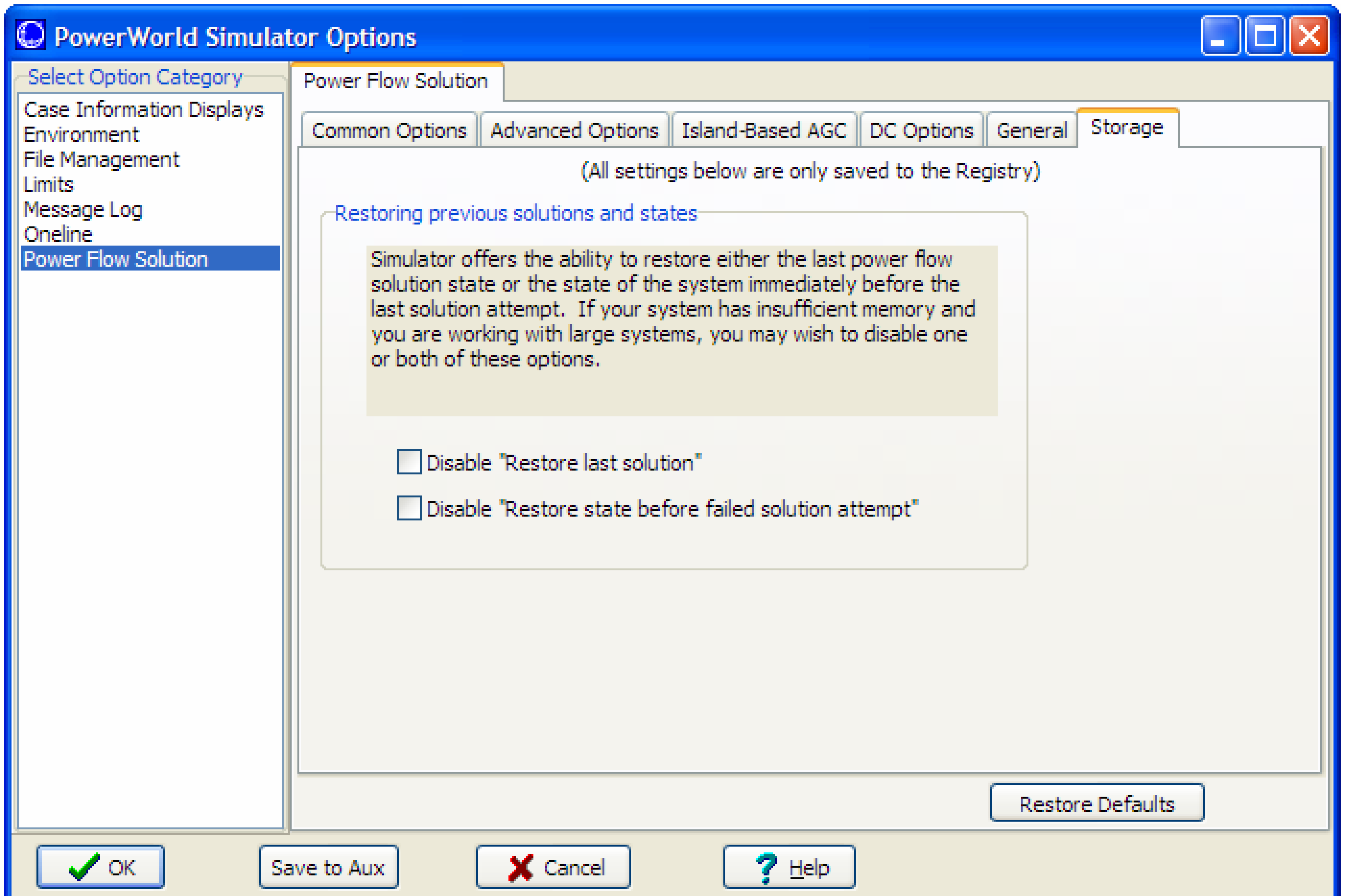


# Simulator Options: Power Flow Solution Page

- General Tab
  - Assumed MVA Per Unit Base
    - MVA base used for the entire case
    - Default is 100 MVA
  - Monitor/Enforce Contingent Interface Elements
    - Determine when the impact of contingent interface elements should be calculated
  - Bus Loss Sensitivity Function
    - Discussed when we go over sensitivities in the Sensitivity Training section

# Simulator Options: Power Flow Solution Page

- Storage Tab



# Islands - Defined

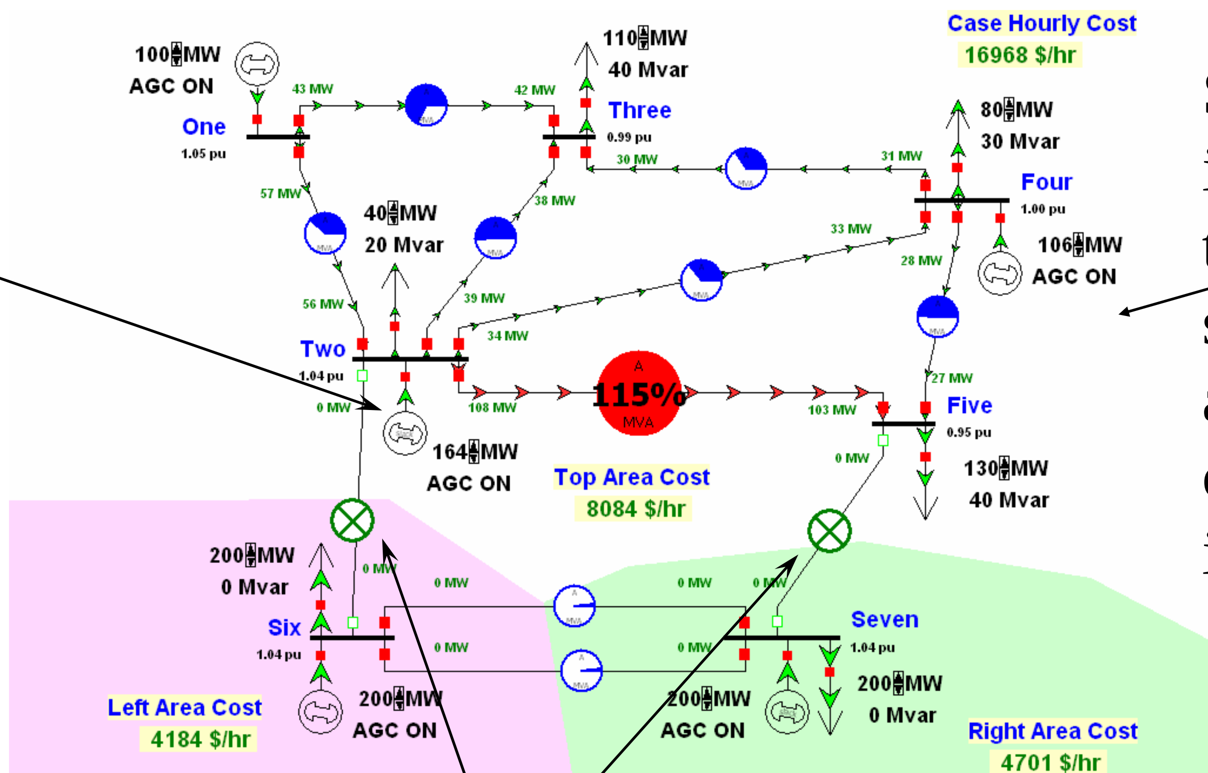
- Often times power system consists of a single interconnected system operating in synchronism
- However sometimes multiple systems exist that are either unconnected, or connected only through DC transmission lines.
- Such systems operate asynchronous with one another and are called “Islands”.
- Each island must have a slack bus.  Check Allow Multiple Islands.

# Multiple Islands in Simulator

- Go to the **Options** ribbon tab → **Simulator Options** → **Power Flow Solution** → **Advanced Options** tab
  - Check **Dynamically add/remove slack buses as topology is changed**
- On the B7FLAT case the slack bus is 7.
- To create two islands, open lines 2-6 and 5-7.
- If new island does not have a slack, Simulator automatically chooses largest generator
- Repeat with **Dynamically add/remove…**unchecked

# Case with Multiple Islands

Simulator has automatically chosen bus 2 as the slack.




Simulator is modeling the two systems as being completely independent

Open tie-lines

# Island Records Display

Case Islands

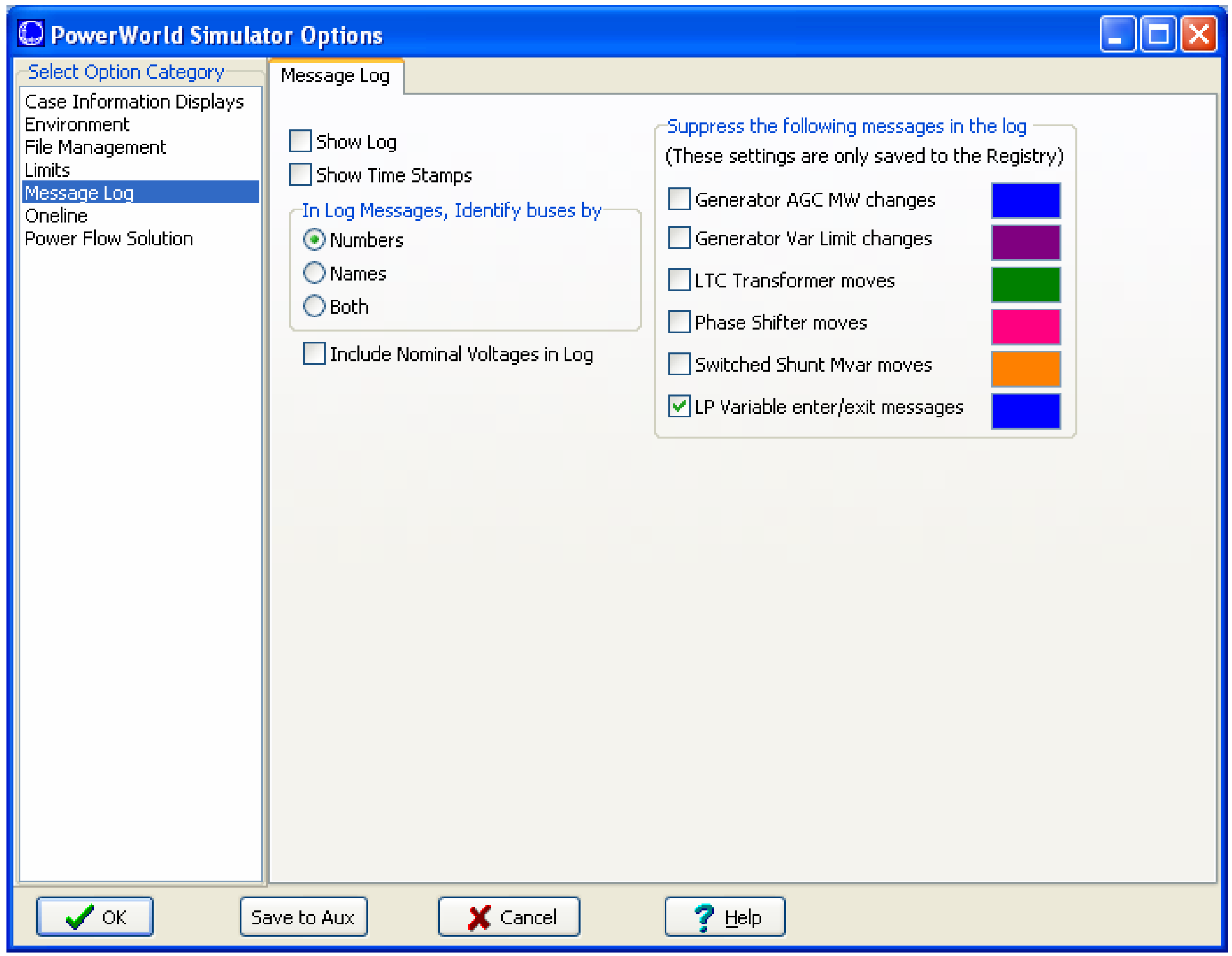
| | Slack Bus Nu | Slack Bus Na | Slack Bus Are | Total Buses | Energized | Gen MW | Gen Mvar | Load MW | Load Mvar | Scheduled Ex |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 7 | RIGHT | 2 | YES | 401.0 | -7.7 | 400.0 | 0.0 | -25.0 |
| 2 | 2 | 2 | TOP | 5 | YES | 369.6 | 129.0 | 360.0 | 130.0 | 25.0 |

**Model Explorer →Aggregations → Island Records** shows information about each island in the case, including its slack bus.

It is not uncommon to have multiple islands. Often cases in the Eastern United States have Five Islands

# Simulator Options: Message Log Page

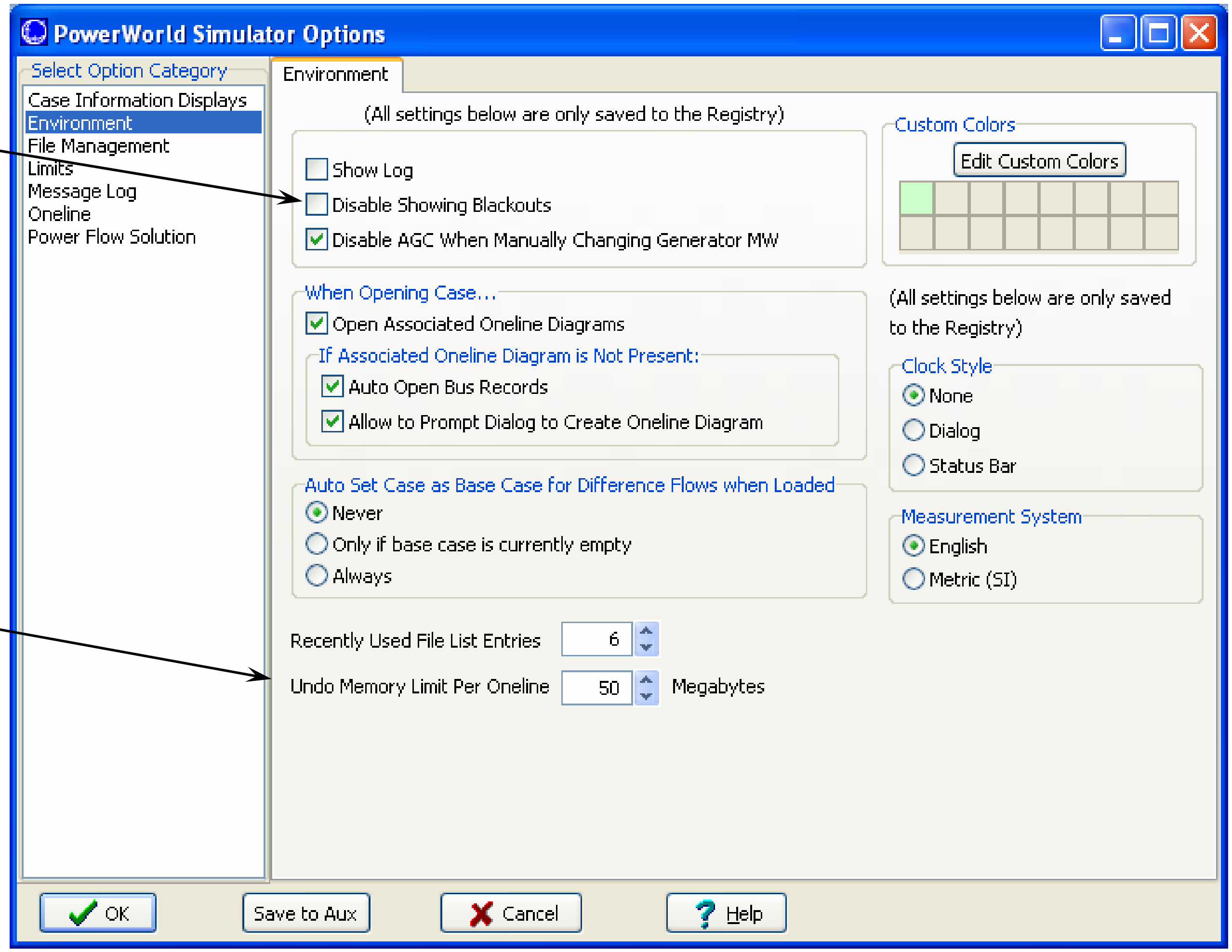
- Customize message log notation, contents, and appearance



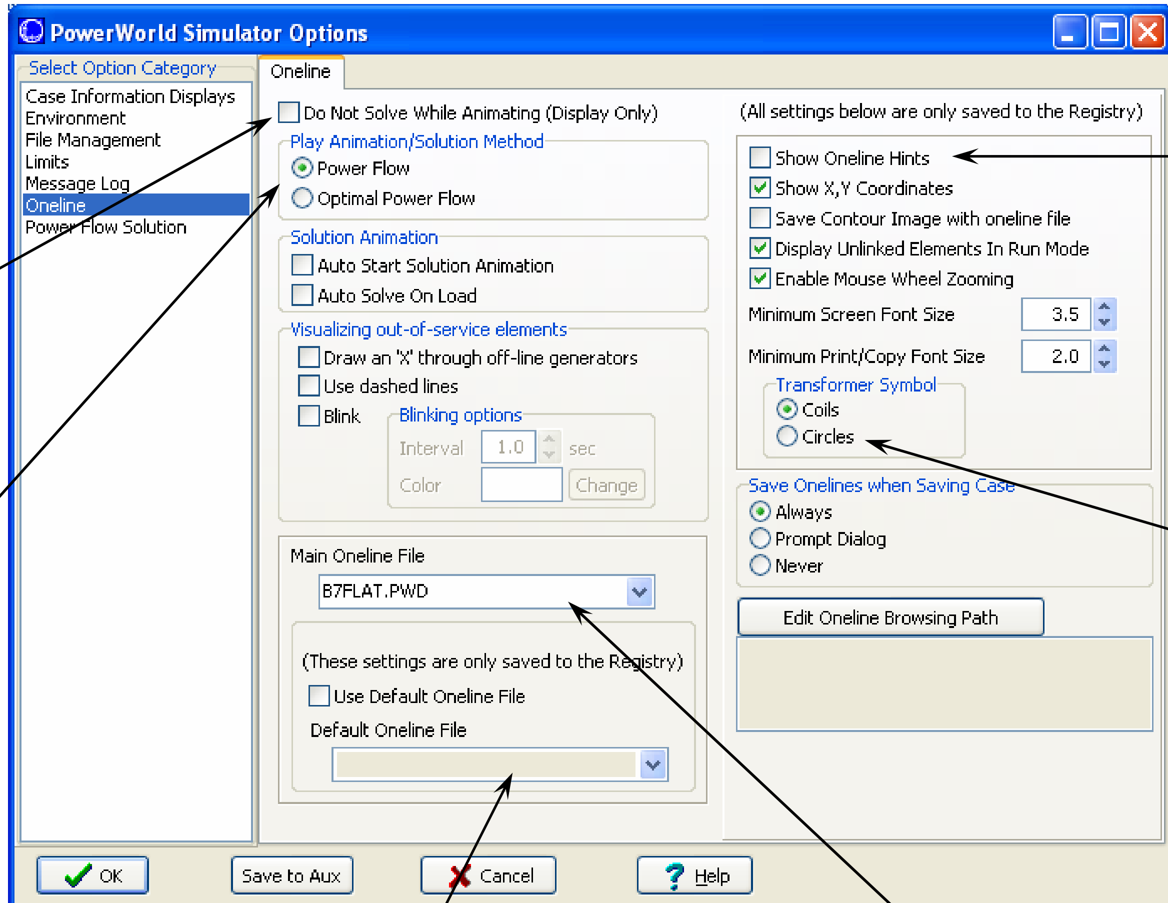
# Simulator Options: Environment Page

Can have "Blackout" appear if case does not converge

Memory limit for Oneline Undo feature



# Simulator Options: Oneline Page




Display only; no simulation

Solution method when animating

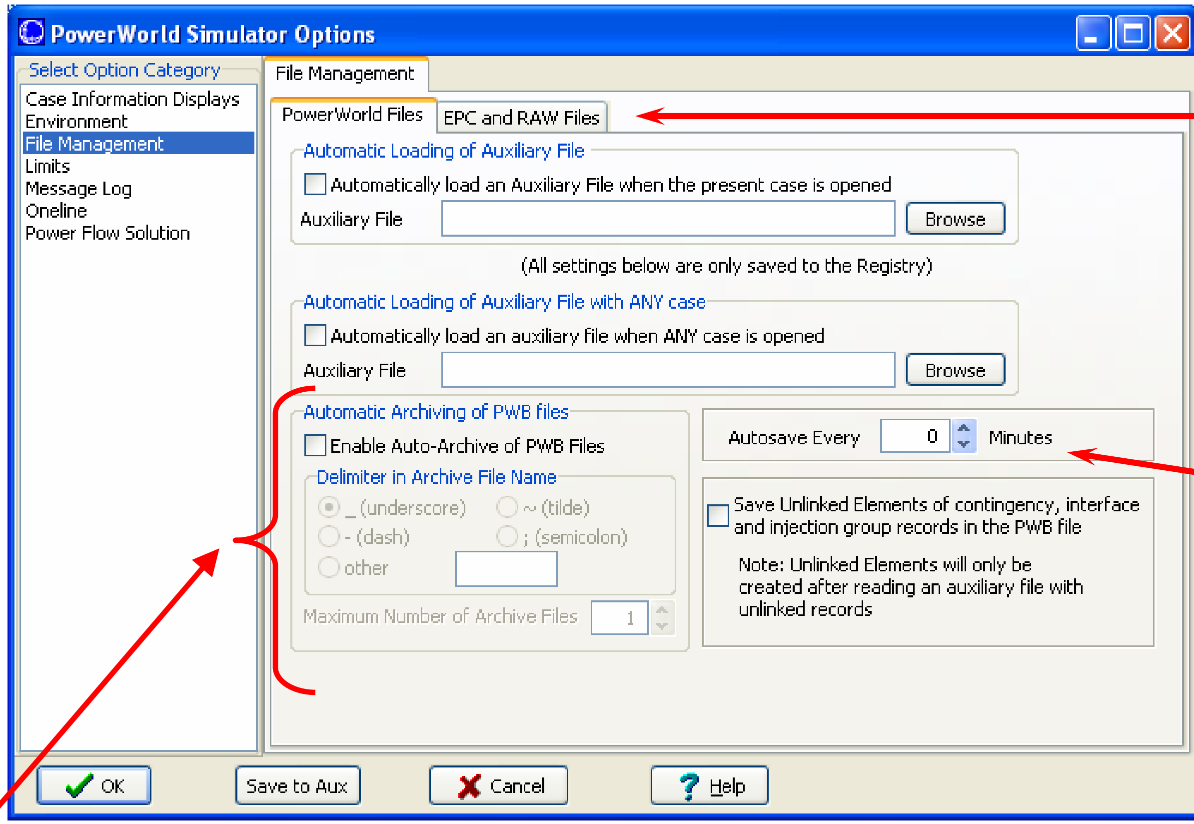
Shows hints when cursor over element

Non-US style XFR symbols

Name of default oneline file to open for ALL cases

Name of main oneline file for CURRENT case

# Simulator Options: File Manage Page



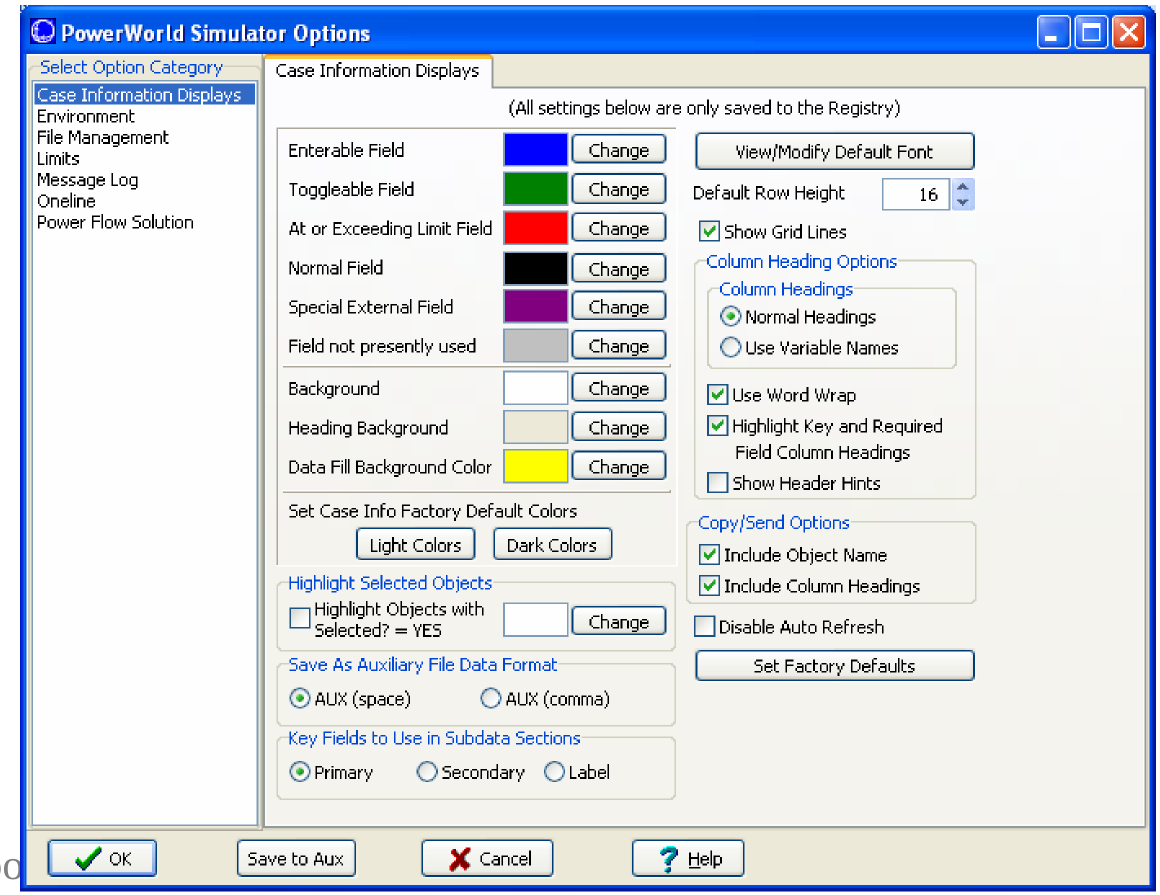

Special options tab for EPC and RAW files

Automatically save over current PWB. “0” means do not Autosave

Enables previously saved PWB files to be automatically archived each time the file is saved with the same name

# Simulator Options: Case Information Displays

- This was covered in an earlier section on Case Information Displays

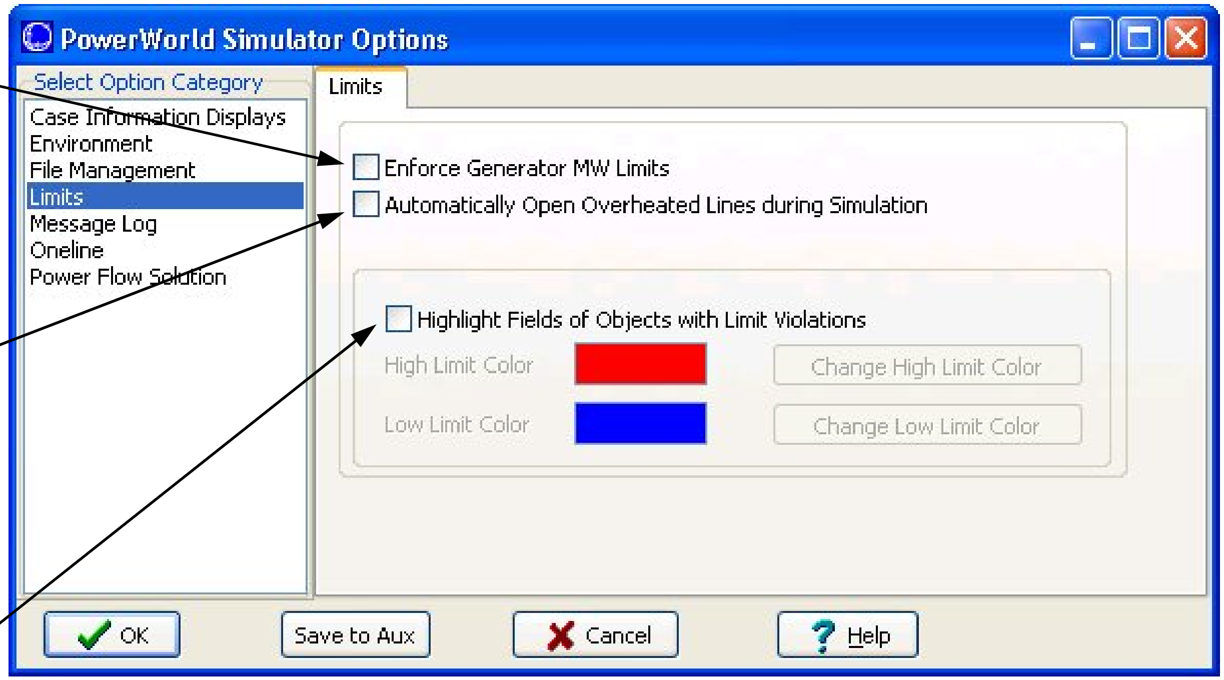


# Simulation Options: Limits Tab

Globally set enforcement of generator limits

Can set lines to open automatically if overloaded for too long in simulation

Text fields can be highlighted if the value they display is violating a defined limit



# Generator AVR

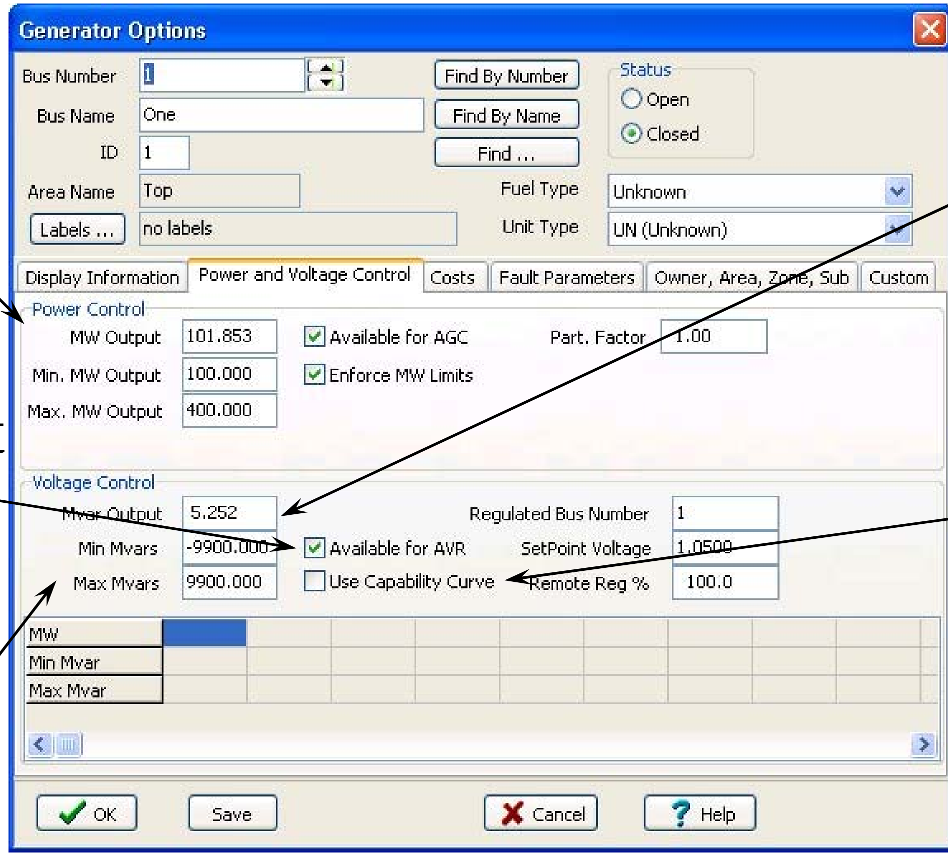
- Generator AVR is integrated directly into the power flow equations. (AVR creates "PV buses")
- Generators on AVR maintain a fixed voltage magnitude at the regulated bus, provided reactive power output is within limits.
- To change options, right-click on generator symbol and select Information Dialog.

# Generator Dialog (Edit Mode)

MW Control will be discussed later

If not checked then Mvar output is fixed

Fixed reactive power limits if capability curve is not being used




Current reactive power output

Check to define and use MW dependent capability curve

# Remote Regulation and Var Sharing

- You may specify a regulated bus number which is not the terminal bus (commonly called "remote" regulation)
- Multiple generators may regulate the same bus.
  - Generators at different buses will share the total Var requirement according to the option selected for sharing vars across groups of buses (Advanced Options Tab of Power Flow Solution Page)
  - Generators at the same bus will coordinate Var outputs so they are within the same relative location inside their Var range
  - Generators can share at the same bus and remotely regulate at the same time. In this case the "regulation percentage" refers to all the generators at the bus

# Defining Reactive Capability Curve

- To use a reactive capability curve, on the Generator Dialog, check **Use Capability Curve**.
- Then use table to edit the curve.  Right-click on a column of table (a point on the curve) to either
  - **insert** a new point (table column)
  - **delete** an existing point (table column)

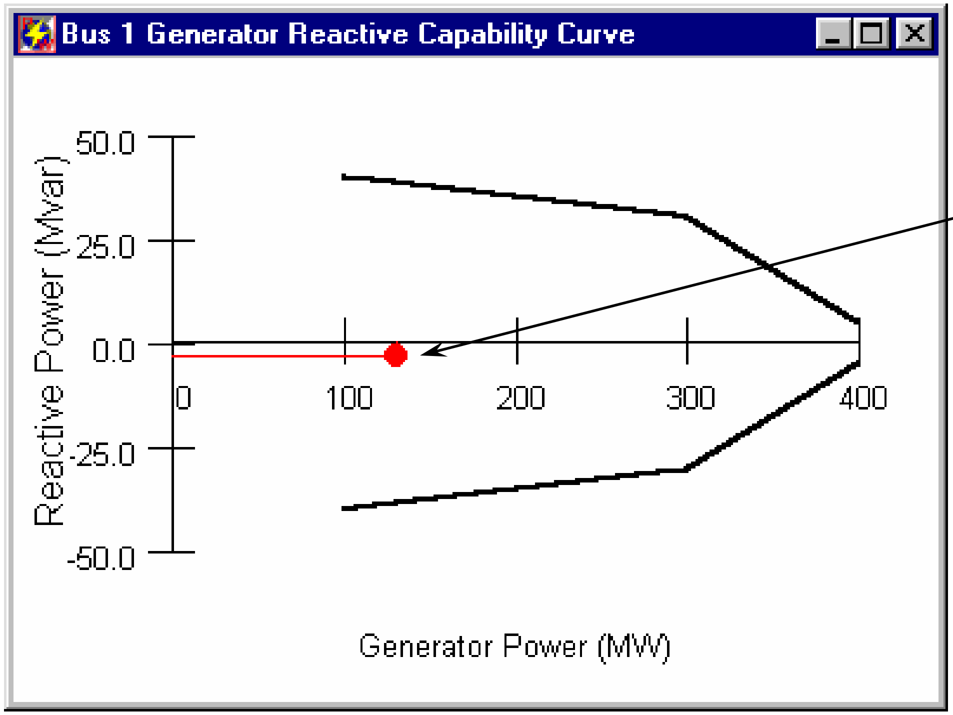
# Reactive Capability Curve

- Enter the following capability curve

| MW | 100.0 | 300 | 400.0 | | |
|---|---|---|---|---|---|
| Min Mvar | -40 | -30 | -5 | | |
| Max Mvar | 40 | 30 | 5 | | |

- You can view a graph of the reactive capability curve by selecting **Reactive Capability Curve** from the generator menu.

# Capability Curve Graph




Current MW and Mvar operating point of the generator

Right-click on generator to view its local-menu

Start the simulation, and then use the spin button to the right of the generator to change the MW output of the generator. Notice how the operating point on the graph changes.

# Saving Reactive Capability in Text File

- All power system data, including the generator reactive capability curve, is saved in PowerWorld Binary format (*.pwb) files
- Reactive capability curve data is not saved in most text-based power flow formats, such as PTI RAW or GE EPC files.
- Simulator provides the ability to save this data in text files for easy transfer between cases.

# Saving in Text Files

- To save reactive capability data in a text file
  - Go to the **Model Explorer → Network → Generators**
  - Right-Click and choose **Save As → Auxiliary File**
  - Choose the filename to save under and Click **OK**
  - You will then be prompted regarding saving the Bid Curve and Reactive Capability Curve data to the AUX file. Choose **Yes** to the Reactive Capability Curve
    - Reactive Capability Curves are stored in SUBDATA sections of the AUX file
  - the *.aux file can then be manually edited

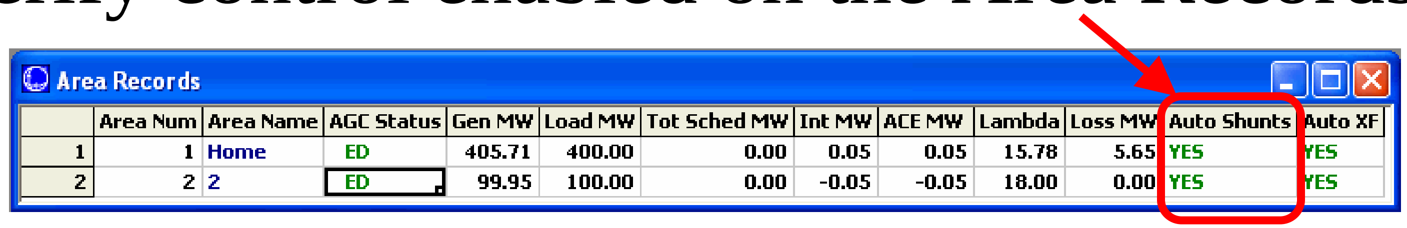
# Switched Shunt Control

- Switched shunts can automatically change their shunt susceptance to control voltage at a regulated bus.
- Switched shunts on continuous control are integrated directly into the power flow equations. (They create "PV buses.")
- Automatic switched shunt control can be disabled in three places
  - for entire case on Simulator Options dialog
  - for area on Area Records display
  - individually on Switched Shunt dialog
  - All three of these flags must be set to enable switched shunt control in order for a shunt to move.

# Switched Shunt Control

- Open Case B5R
- Verify the switched shunt control is enabled on Power Flow Solution Options dialog


- Verify control enabled on the Area Records



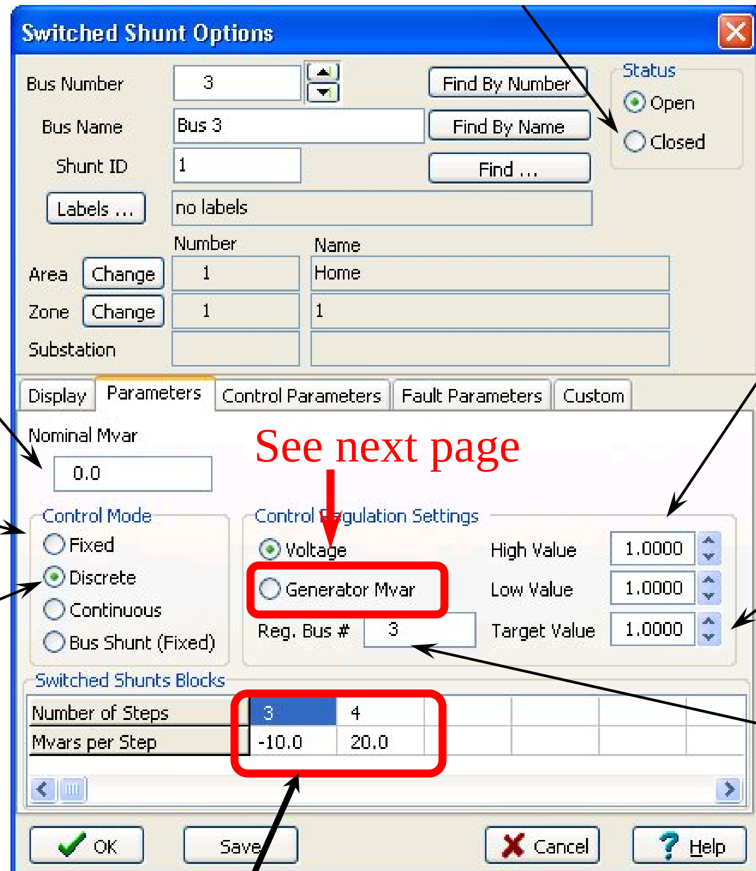

| | Area Num | Area Name | AGC Status | Gen MW | Load MW | Tot Sched MW | Int MW | ACE MW | Lambda | Loss MW | Auto Shunts | Auto XF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Home | ED | 405.71 | 400.00 | 0.00 | 0.05 | 0.05 | 15.78 | 5.65 | YES | YES |
| 2 | 2 | 2 | ED | 99.95 | 100.00 | 0.00 | -0.05 | -0.05 | 18.00 | 0.00 | YES | YES |

- Right-click on switched shunt shown at bus 3 to display the Switched Shunt dialog.

# Switched Shunt Dialog

Status must be closed to work

Actual Mvar will differ if bus voltage is not 1.0 pu.




In discrete mode high value must be strictly greater than low value

Automatic control requires the mode be either discrete or continuous

When a value goes out of range, Simulator algorithms attempt to set the value to the target

Bus Shunt (Fixed) is the same as Fixed (flag used to support GE EPC file format)

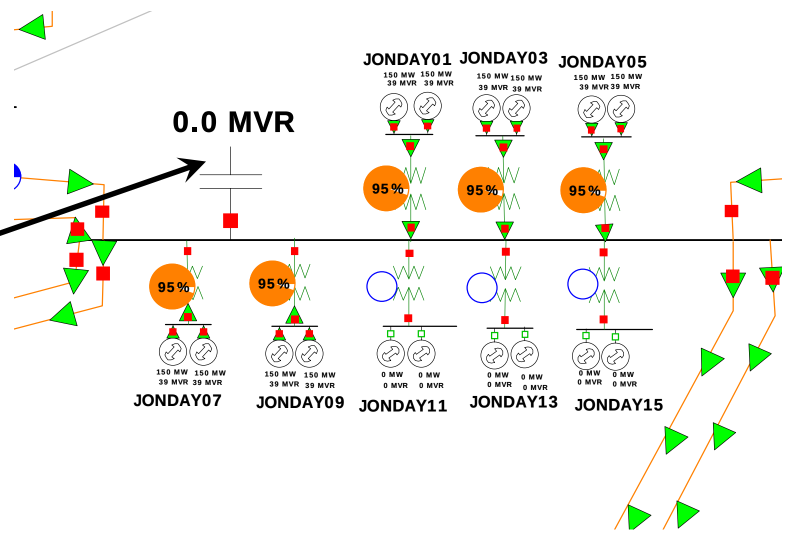
Regulated bus usually the terminal bus

Specify the "blocks" of Mvar which are available for shunt dispatch. This example demonstrated a shunt which has the ability to provide -30, -20, -10, 0, 20, 40, 60, or 80 Mvars

# Switched Shunt Control of Generator Mvar Outputs

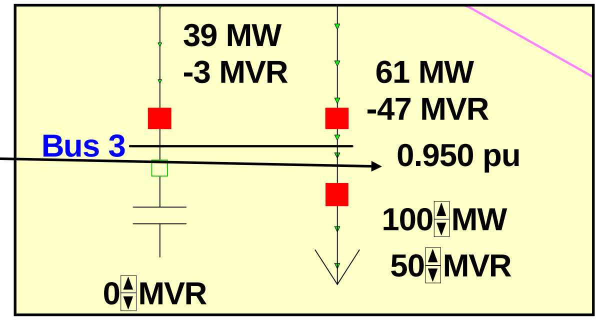
- Switched Shunts may be used to control the Mvar output of generation
- To do this change the **Control Regulation Settings** to *Generator Mvar*
  - Setting **Reg. Bus** now means to control the total generator Mvar output for generators which control the voltage at the bus specified.

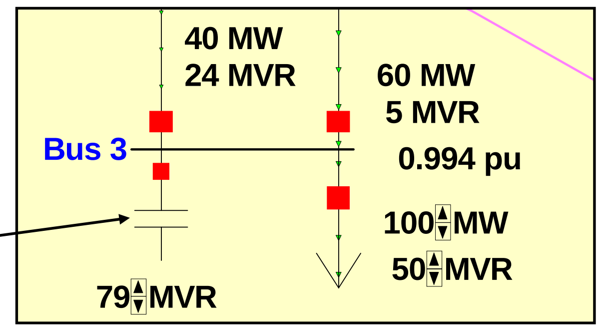
You could set this shunt to control the total generator Mvar output of all 16 generators controlling it's terminal bus

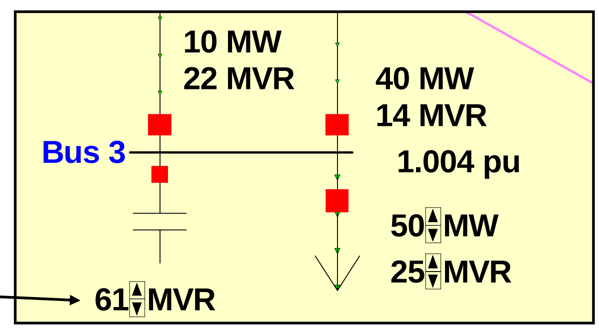


# Example Shunt on B5R Case

- Bus 3 presently has a voltage of 0.950 per unit.
- From earlier slide, we set the control range for the shunt to 0.99 to 1.00 per unit, and switched in the shunt
- This results in the shunt moving to 80 Mvar nominal
- If you decrease the load at the bus, the voltage starts to increase, so eventually the shunts reduces



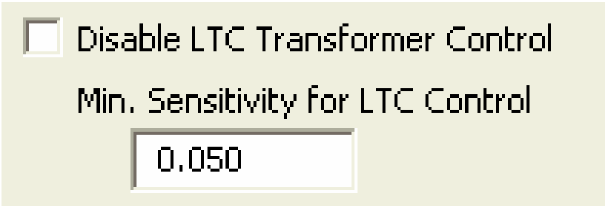



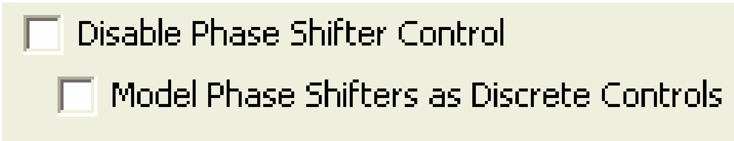
# Transformer Tap Control

- Some transformers can automatically change either their tap ratio or their phase angle to control either
  - voltage - Load Tap Changing (LTC) transformer
  - MVAR flow - LTC transformer
  - MW flow - phase shifter
- Again, Automatic control can be disabled in three places
  - for entire case on **Simulator Options** dialog
  - for area on **Area Records** display
  - individually on **Transmission Line/Transformer** dialog
  - All three of these flags must be set to enable switched shunt control in order for a shunt to move.

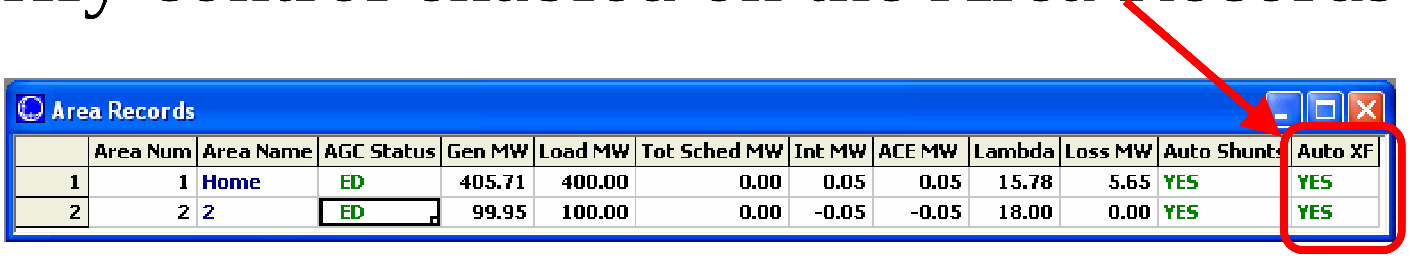
# Transformer Control

- Verify the transformer control is enabled on Power Flow Solution Options dialog




- Verify control enabled on the Area Records



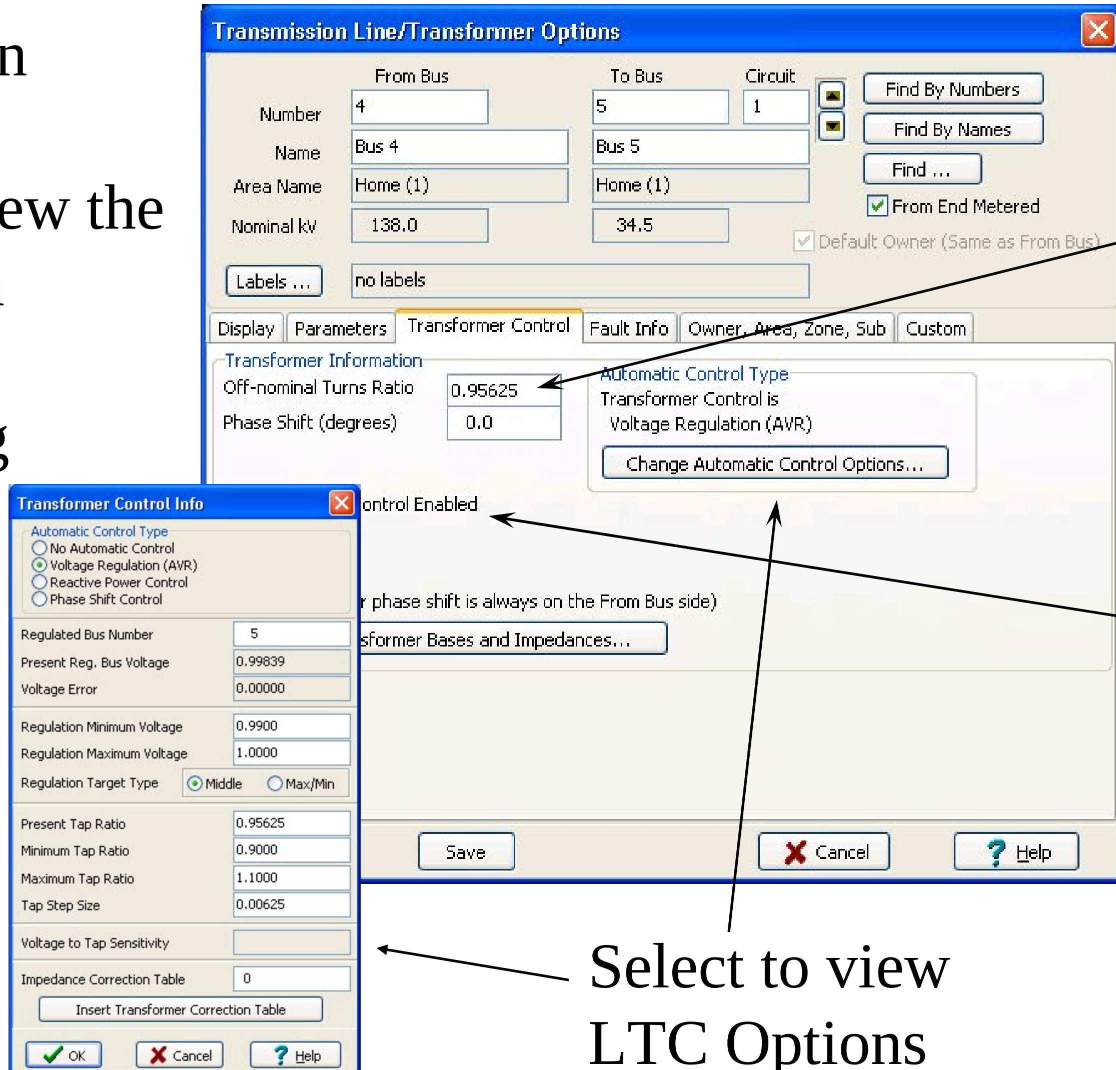

| | Area Num | Area Name | AGC Status | Gen MW | Load MW | Tot Sched MW | Int MW | ACE MW | Lambda | Loss MW | Auto Shunts | Auto XF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Home | ED | 405.71 | 400.00 | 0.00 | 0.05 | 0.05 | 15.78 | 5.65 | YES | YES |
| 2 | 2 | 2 | ED | 99.95 | 100.00 | 0.00 | -0.05 | -0.05 | 18.00 | 0.00 | YES | YES |

- Right-click on transformer shown between buses 4-5 to display the transformer dialog.

# LTC Transformers

Right-click on transformer symbol to view the Transmission Line/Transformer dialog

Transformer LTC options



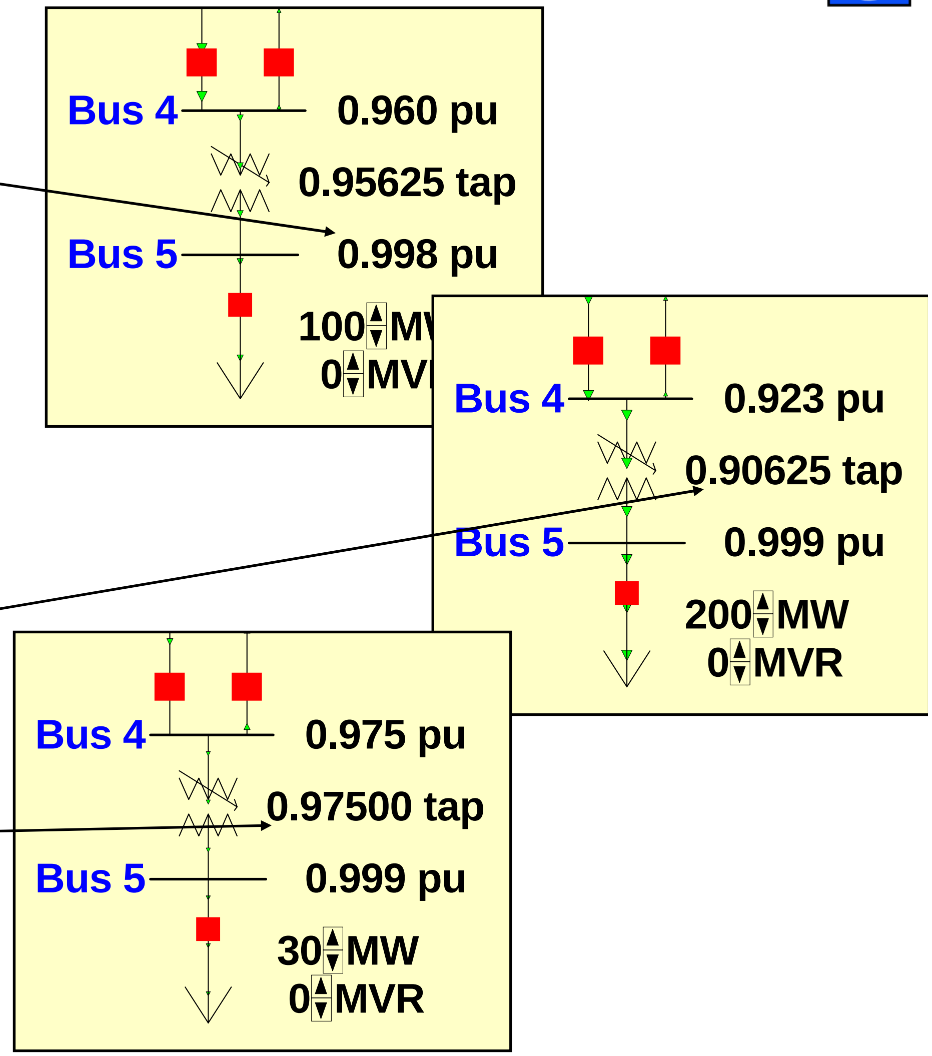

Current off-nominal turns ratio and phase shift

Must be checked to enable control

Select to view LTC Options

# Example LTC on B5R Case

- Bus 5 starts with a voltage of 0.998 per unit
- On previous slide we showed that tap (on the bus 4 side) was set to control voltage at bus 5 between 0.99 and 1.00
- As we increase load tap moves
- As we decrease load tap moves



# Detailed Overview of PowerWorld Simulator's Power flow

Special Pre-processing Techniques

Power Flow Algorithm

Control Switching Hierarchy

MW Control

# What Does It Mean to do a Single Solution?

- 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 iterates 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

Traditionally called the *Power Flow Solution*

Voltage Control Loop also covered in this section

MW Control Loop also covered later

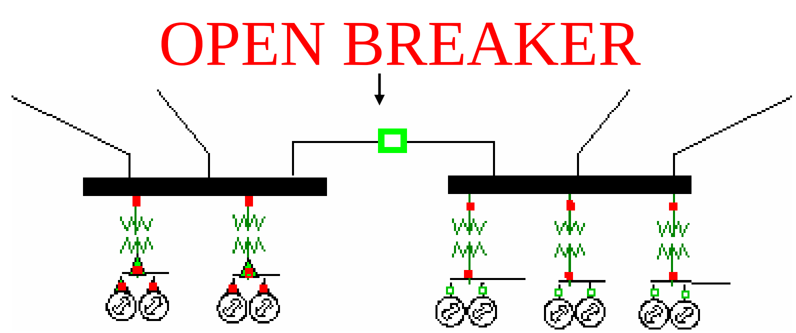
# Pre-processing

- Angle Smoothing
  - Reduces large angle differences across transmission elements that have recently been closed in to reduce initial power flow mismatches
  - Previously if you closed in a line with a large angle difference, the power flow would diverge

# 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, then the generator is internally turned off of voltage regulation

If a generator on left are set to control voltage at the bus on the right, then 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

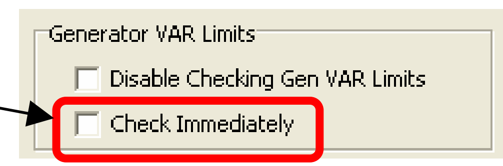
- MW Control (Outer Loop)
  - Repeat
    - Voltage Controller Loop
      - Inner Power Flow  Loop
    - Change generation/load to meet ACE requirements
      - Redispatches generation and/or load using the selected AGC control method for each area (superarea, or island)
  - Until no more generation/load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

# Power Flow and Control Loop

- Voltage control switching and Inner Power Flow Loop
  - Repeat
    - 1: Inner Power Flow loop
    - 2: Generator MVAR Limit Checking
    - 3: DC Line Solution
    - 4: Switched Shunt Control Switching
    - 5: Transformer switching
  - Until no more control switching is required

# Step 1: Inner Power Flow Loop

- Step 1: Repeat (Inner Power Flow loop)
  - Evaluation Mismatch
  - Generator MVAR output automatically calculated for PV buses
  - Optionally (enforce Generator MVAR limits at each step)
  - Perform power flow step
    - » Newton's Method (this is in rectangular form)
    - » Decoupled Power Flow
    - » Polar Form Newton's Method
- Until no more mismatch



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

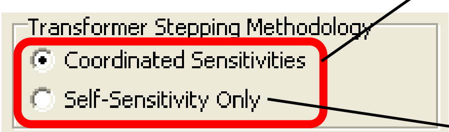
- Step 2: Generator MVAR Limit Check
  - Backs off or enforces MVAR limits
  - Checks for controller oscillation
    - » Generators that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors
    - » Incorporates voltage vector changes by processing generators in series
- Step 3: Solve DC line equations

# 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 which maintains VAR reserves)
    - » Shunts are adjusted by one at a time in series with each shunt only considering it's impact on the regulated bus' voltage. The interaction of 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: Transformer Switching

- Step 5: 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




  - Checks for controller oscillations
    - Transformers that appear to be oscillating between control settings are internally set off of control
  - Updates mismatch and voltage vectors

# Complete Process

- Pre-processing
  - Angle Smoothing, Remote Viability Check, Area Generator Estimation
- Repeat (MW Control Loop)
  - Repeat (Controller Loop)
    - 1: Repeat (InnerPower Flow loop)
      - Evaluation Mismatch
      - Optionally (enforce Generator MVAR limits at each step)
      - Perform power flow step
        - » Newton's Method
        - » Decoupled Power Flow
        - » Polar Newton
    - Until no more mismatch (or max iteration)
    - 2: Generator MVAR Limit Checking
    - 3: DC Line Solution
    - 4: Switched Shunt Control Switching
    - 5: Transformer 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