Transient Stability Analysis with PowerWorld Simulator

T3: Transient Stability Basics

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Transient Stability Basics

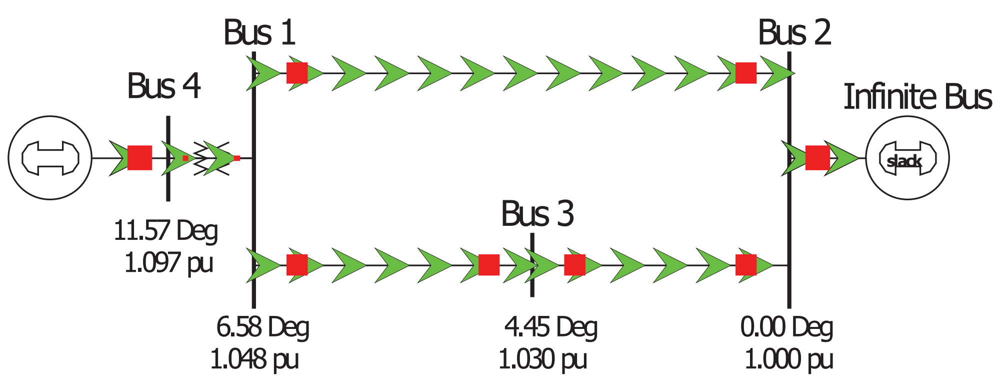
- Overview of the Transient Stability Add On Functionality
  - Initialization procedure
  - State equations
  - Numerical integration procedure
  - Updating the network
- Special features of Simulator's Transient Stability Add On
- Basic Simulation Control
  - General and Power System Model Options
  - Running a simulation

"Typical" Transient Stability Operation

- The procedure for a "typical" transient stability study is straightforward
  - Study assumes that the transient stability models have been saved in the *.pwb file and storage/plotting variables of interest (up to and including every is already defined)
- Open *.pwb file, select "Add-Ons, Transient Stability" to display Transient Stability Analysis Form.
- Click "Run Transient Stability"

Basic Simulation Control

- Open "Example_13_4_WithPlot" – this case has already been set up
- Single-machine infinite-bus system with 4 buses
- Initial power flow solution is shown below



"Example_13_4_WithPlot"

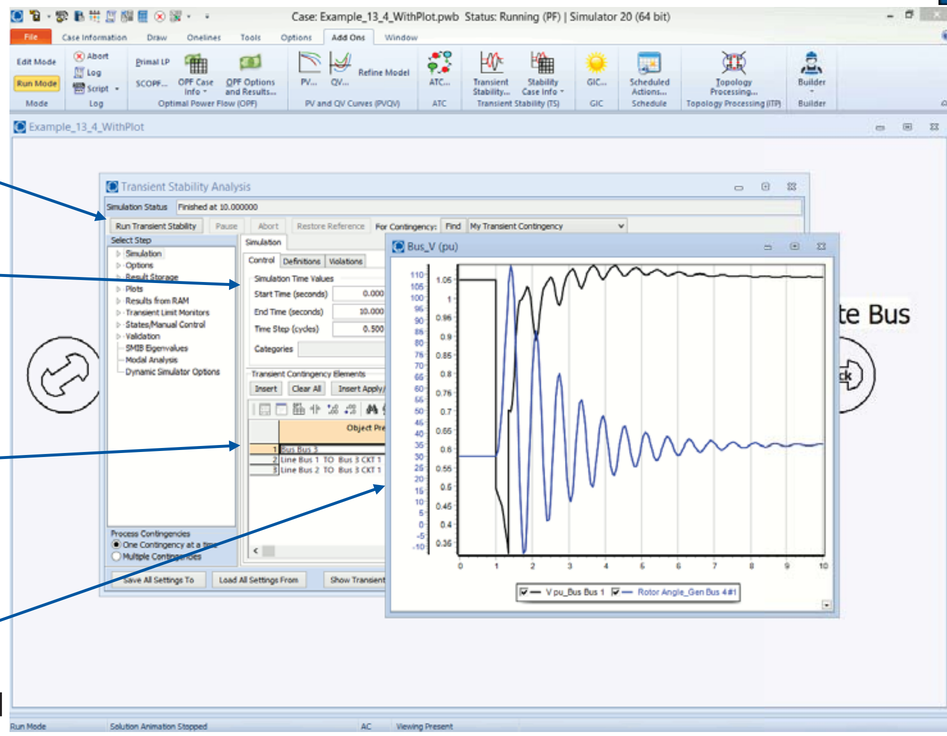
Display After Selecting "Run Transient Stability"

The most important button

The Start Time, End Time, and Time Step

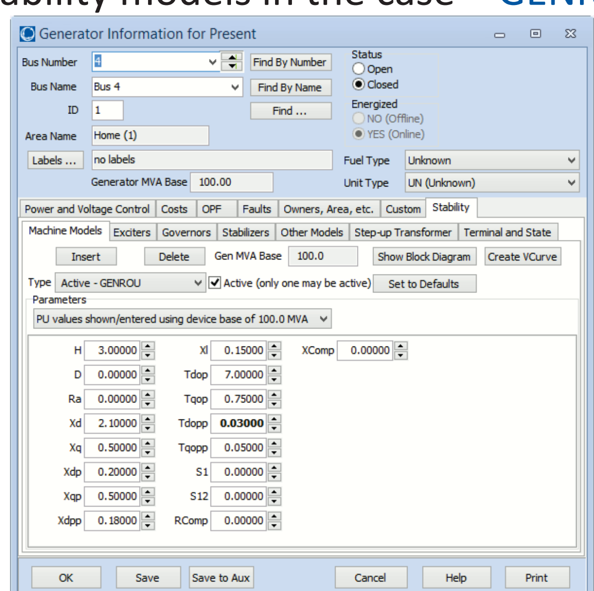
How the transient stability contingency is defined

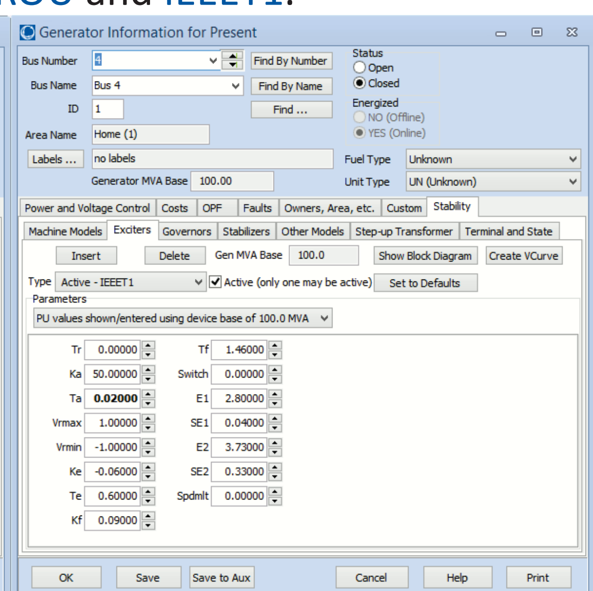
Predefined plots shown automatically at end



Going Deeper: Looking at the Generator Models

Right-click on the generator at bus 4 and select "Generator Information Dialog." Select the "Stability" tab to view the transient stability models in the case – GENROU and IEEET1.





Generator Dialog

"Example_13_4_WithPlot"

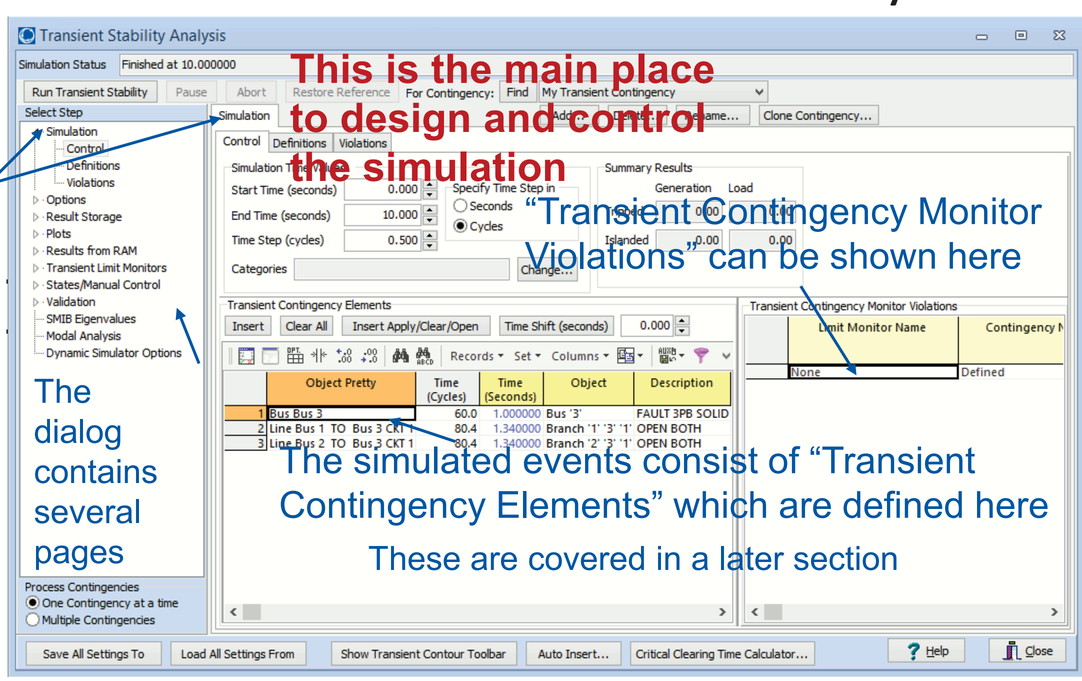
Basic Simulation Control

- How do you design and control the simulation?
- Transient Stability Dialog
  - Customize the options to fit your needs
  - Setup automatic plotting and storing of results
  - Specify events to occur
  - Setup and run the simulation
  - Step through the simulation using States/Manual Control
- More details will be covered in later sections
- Here we'll look at the Transient Stability Dialog and cover the basics of running a simulation

Transient Stability Dialog

Go to the **Add Ons** ribbon tab and select **Transient Stability**

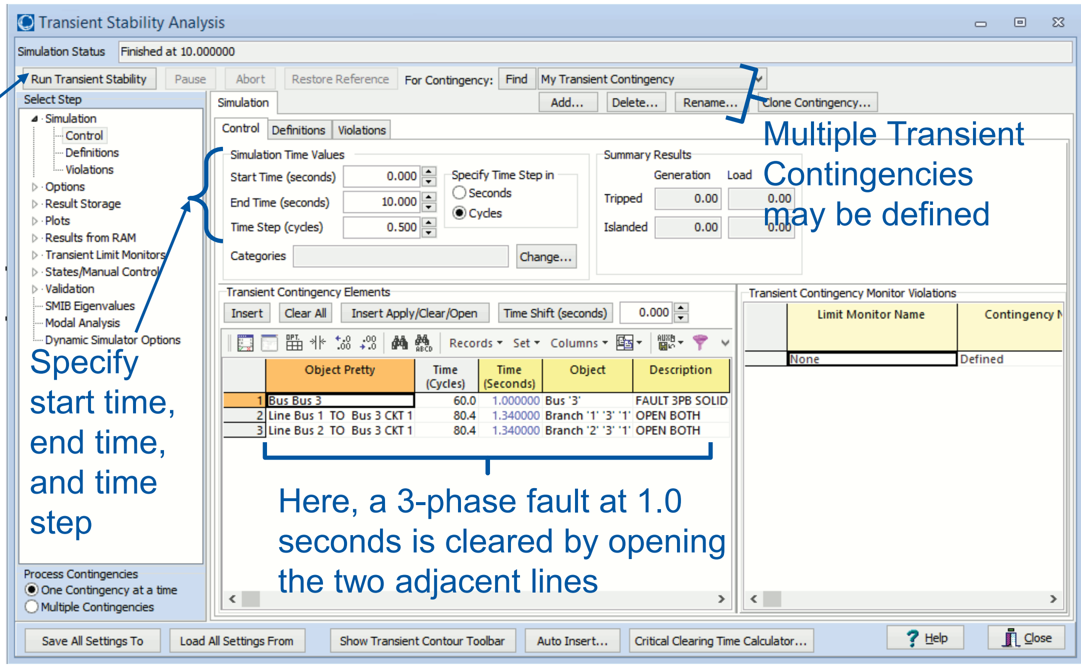
Simulation page of the Transient Stability Analysis Dialog



"Example_13_4_WithPlot"

Simulation Dialog

The simulation is designed and typically run from here



"Example_13_4_WithPlot"

Transient Stability Dialog Pages Allow for Customization

Simulation

Define events, start time, end time, and time step

Options

General, Power System Model, Results, Generic Limit Monitors

Results Storage

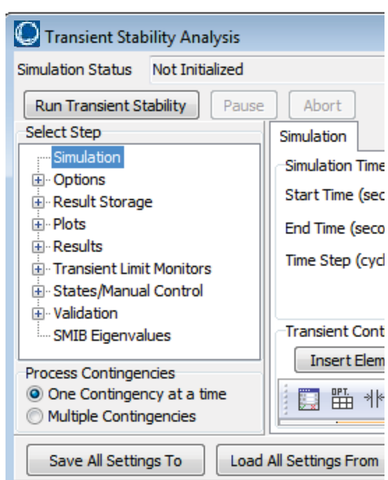
Specify what to store during the simulation for viewing, plotting, and contouring

Plots

Create plot descriptions that can be automatically generated upon completion of a transient stability run

Results

View numeric results of a simulation and a summary of events that occurred



SMIB Eigenvalues

Perform Single Machine Infinite Bus analysis on each generator

Validation

Options to validate the data for possible errors and warnings

States/Manual Control

Manually step through the simulation and view initialized states and initial limit violations

Transient Limit Monitors

Set monitors to check for stability criteria violations during the simulation

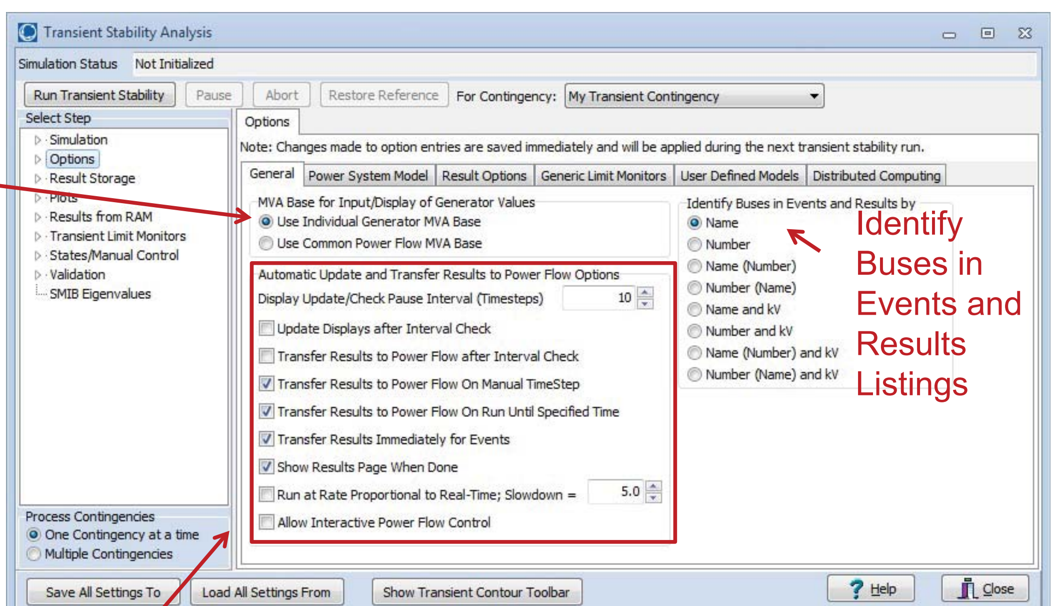
Transient Stability Options: General

- Options to Transfer Results
  - Interval check
  - After manual time step
  - After manual control "Run Until Time"
  - Immediately after events
- Run at a Rate Proportional to Real-Time
  - Runs the simulation at a slower rate for educational/demonstrational purposes
  - i.e., to view a contour of transient stability data changing with time
  - Does not actually change the time step
  - Slowdown = 5 runs at 1/5 of real-time rate

Transient Stability Options: General

- Open the Options page to the General tab

Option affects Generator Dialog inputs (Case Info Displays always show values on generator MVA base)

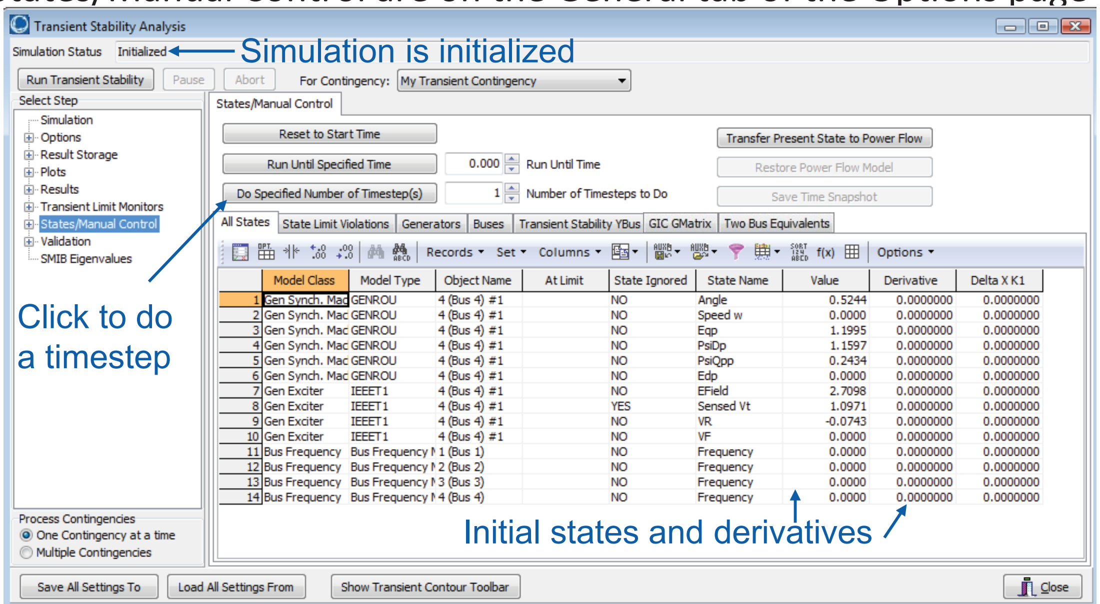


Identify Buses in Events and Results Listings

Options for transferring results to power flow are discussed during Manual Control examples

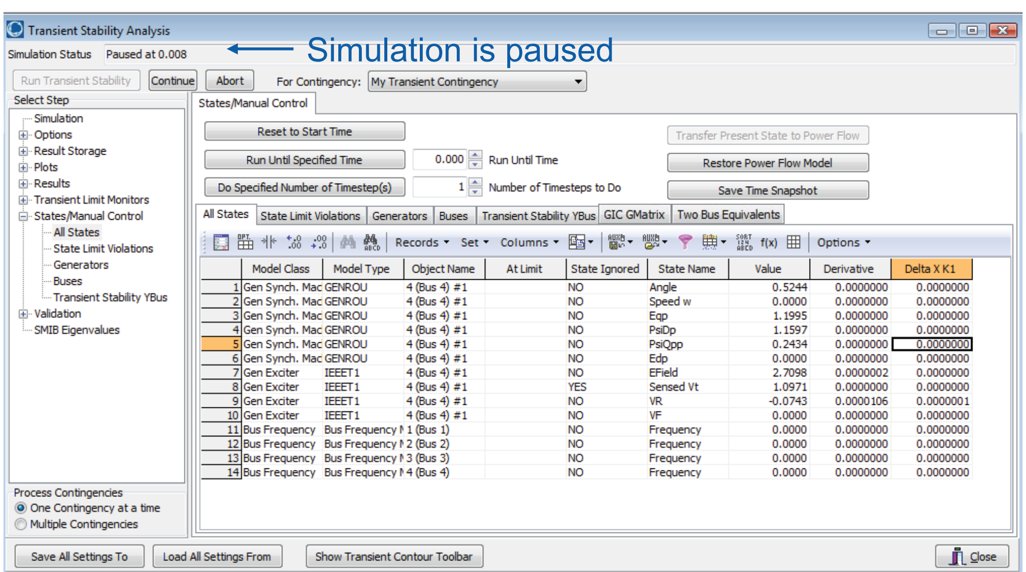
States/Manual Control

- In addition to running the simulation, you can also step through it
- Go to the States/Manual Control page - options related to States/Manual Control are on the General tab of the Options page



States/Manual Control

- Click "Do Specified Number of Timesteps" – the simulation will take one step and then pause
- Dialog now shows the values after 1 time step

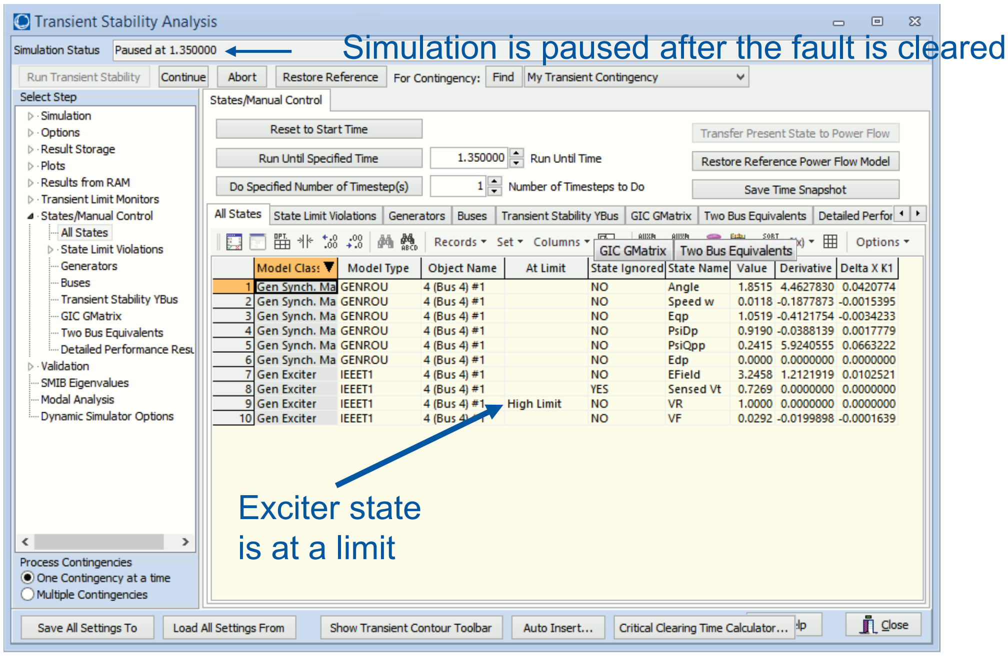


This page can be used as a debugging tool for your simulations

Can also help to identify incorrect parameters

States/Manual Control

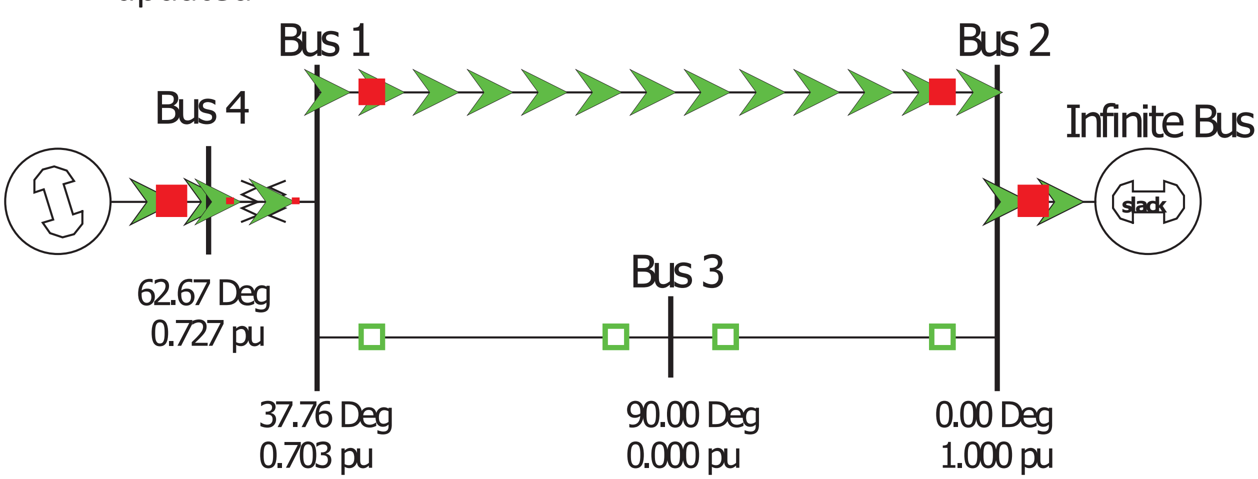
Now, enter 1.35 seconds for “Run Until Time” and click “Run Until Specified Time”



“Example_13_4_WithPlot”

States/Manual Control

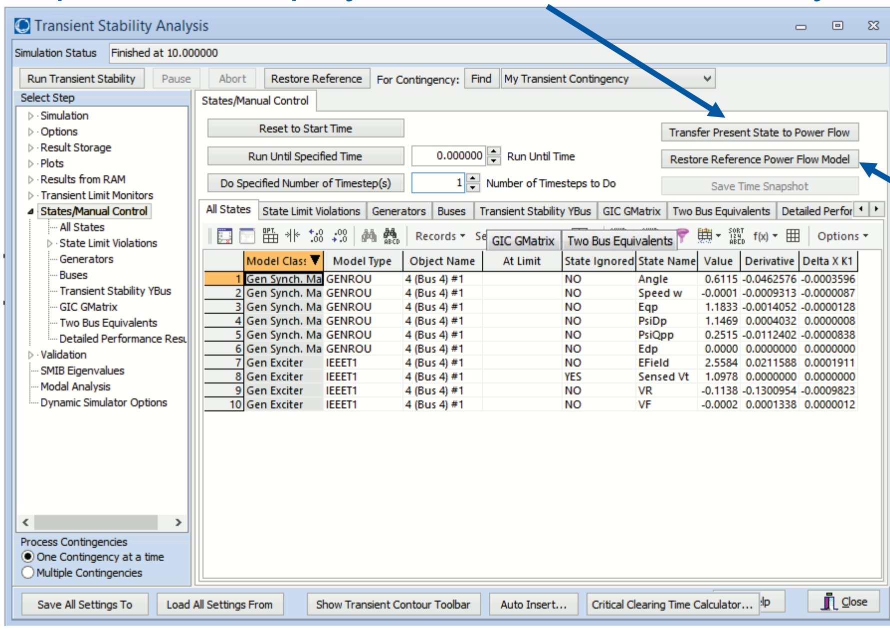
The “Transfer Results to Power Flow on Manual TimeStep” option was checked, so the power flow and the oneline were updated



“Example_13_4_WithPlot”

States/Manual Control

Can click “Transfer Present State to Power Flow” to transfer the state and update the display with the transient stability results

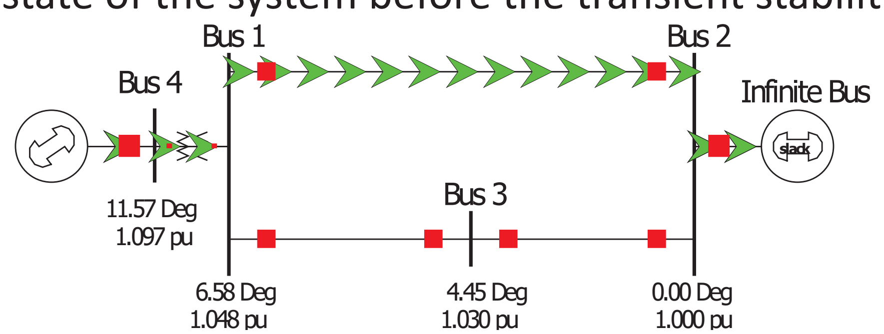


Option to restore state prior to transient stability run

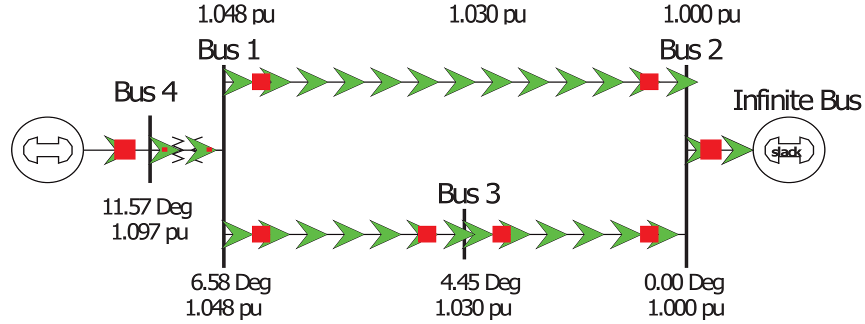
States/Manual Control

- Click “Restore Power Flow Model” to restore the power flow state of the system before the transient stability run

Restored model, unsolved

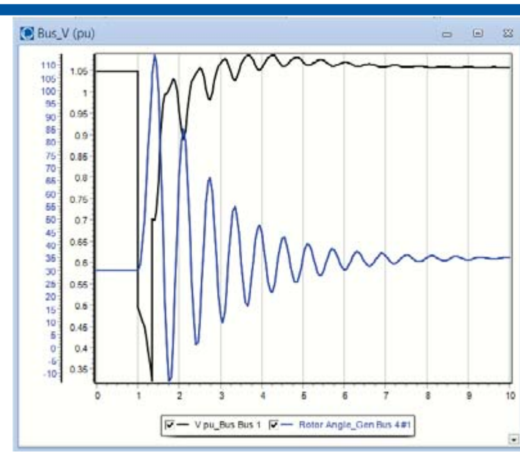


Restored model after a power flow solution



Run a Simulation

- On the States/Manual Control page, click “Reset to Start Time”
- This reinitializes the simulation
- Then, go back to the Simulation page
- Click on “Run Transient Stability” to solve- the simulation will run for 10 seconds
- After the run, the plot to the right will be automatically generated



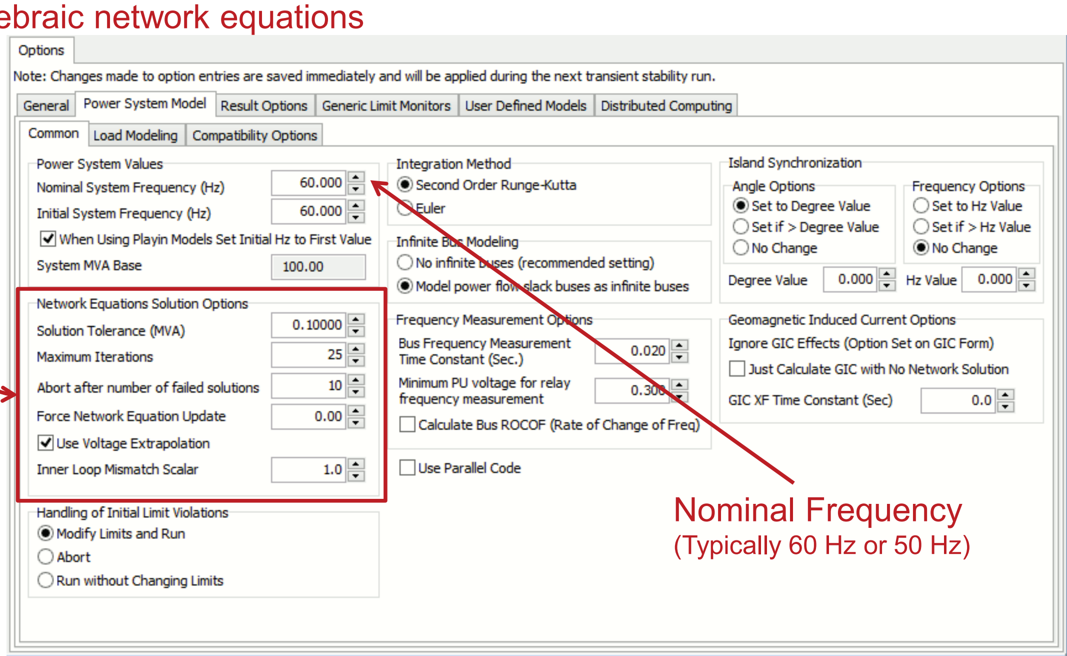
Resultant plot of Bus 1 voltage and Generator 4 rotor angle

Lots of options are available for customizing the appearance of the plots and for exporting plot information. These will be talked about later in the Plot Definition Section.

Transient Stability Options: Power System Model

- Open the Power System Model page to the General tab

Options related to the solution of the algebraic network equations



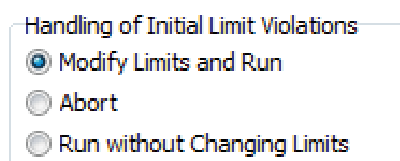
Nominal Frequency
(Typically 60 Hz or 50 Hz)

Transient Stability Options: Power System Model - Common

Network Equation Solution Options

- Solution tolerance and maximum iterations
  - For transient stability power flow algorithm only
- Force network equation update
  - Specify a time for a full network equation update, can be helpful to avoid small oscillations caused by small mismatches
- Use voltage extrapolation
  - Estimate the voltages based on the voltage at the last three time steps, aids in the initial guess of the network equation voltages and helps speed up the solution
- Inner loop mismatch scalar
  - When network equation solutions are done as an intermediate part of the numerical integration method, allowing this scalar to be larger than 1 allows the network equation solution to have a larger mismatch

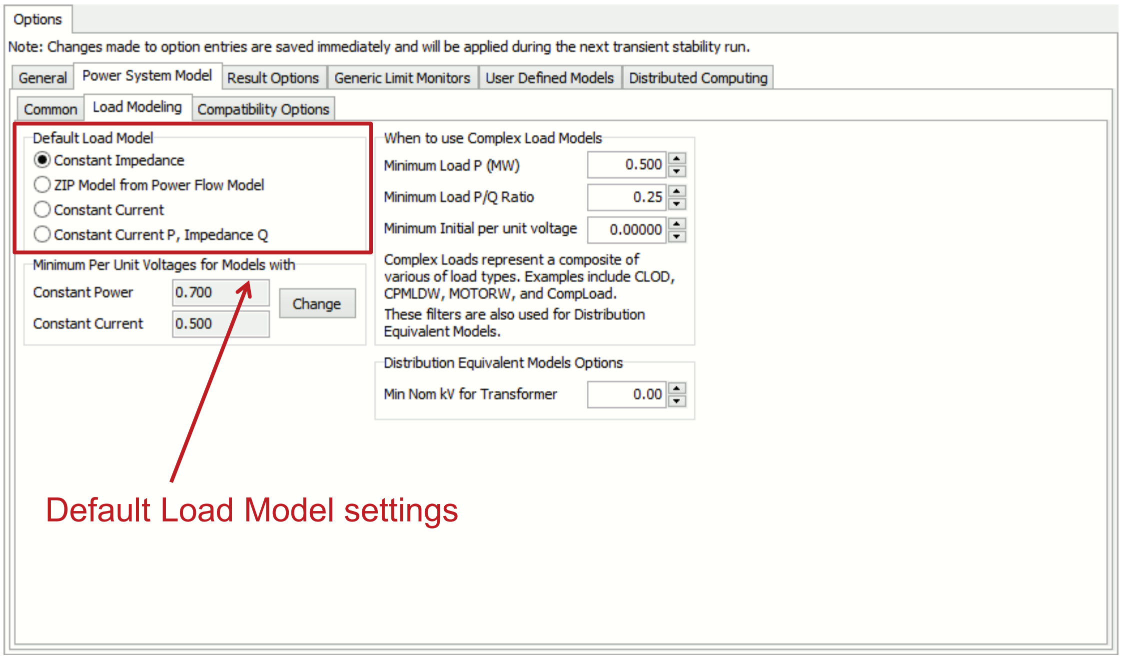
Transient Stability Options: Power System Model - Common



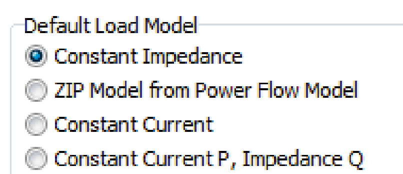
- Integration Method
  - Second Order Runge-Kutta
  - Euler
- Infinite Bus Modeling
  - Model the island slack bus as a constant voltage and angle (essentially it is a generator with infinite inertia)
  - Infinite buses do not exist in real systems so normally this should NOT be done
  - Primarily intended for academic audiences
- Handling of Initial Limit Violations
  - There are many limits associated with dynamic models (exciters, governors, and over-excitation, etc…)
  - Theoretically, there should be no violations of these limits in the steady state solution
  - This option determines what Simulator does if there are violations in the initial conditions
  - Default action is to modify the limit value so that the system is initially in steady-state
- Include GIC Effects
  - This will include the Geomagnetically Induced Current effects into transient stability simulation

Transient Stability Options: Power System Model

- Open the Power System Model page to the General tab



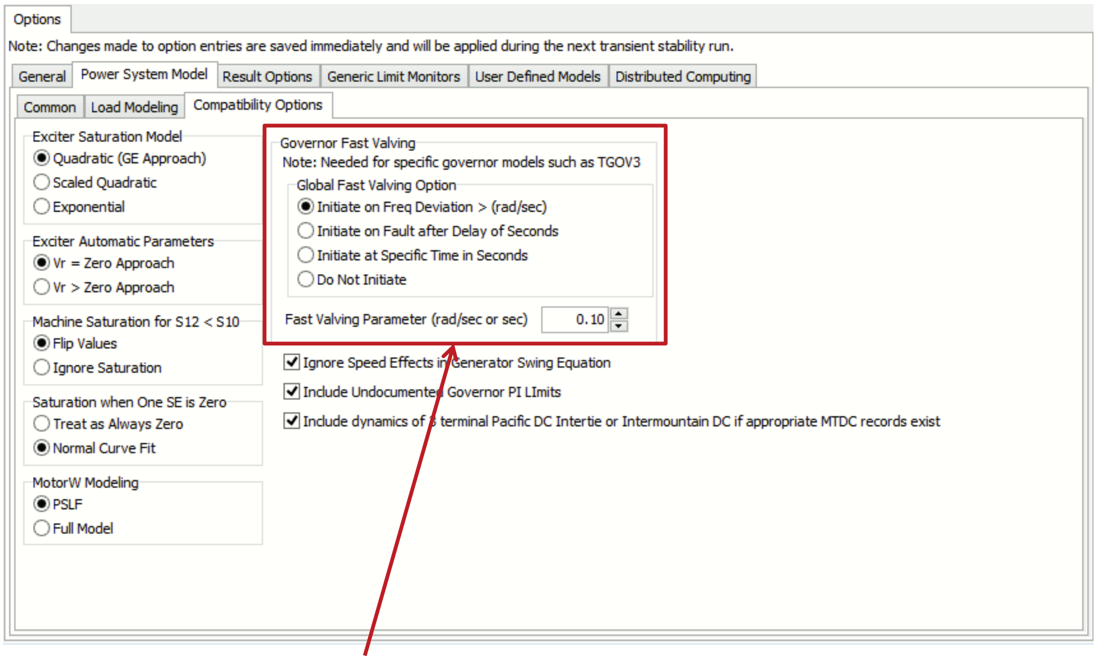
Transient Stability Options: Power System Model – Load Modeling



- Default Load Model
  - It is best to define a system-wide load model explicitly
  - This option is applied to loads with no specified dynamic model
- When to use Complex Load Models (CLOD, CMPLDW, MOTORW and CompLoad)
  - Minimum Load P (MW) to insert complex models
  - Minimum Load P/q Ratio
  - Minimum Initial per unit voltage
- Distribution Equivalent Models Options
  - Minimum Nominal KV to add the Transformer

Transient Stability Options: Power System Model – Compatibility

- Open the Power System Model page to the General tab



Special options for governors using Fast Valving such as TGOV3

Transient Stability Options: Power System Model

- Exciter Saturation Model
  - Quadratic → $S(x) = B^*(x - A)^2$ (GE PSLF)
  - Scaled Quadratic → $S(x) = B^*(x - A)^2$ / input (PTI PSS/E)
  - Exponential → $S(x) = B^*x^A$ (BPA IPF)
- Exciter Automatic Parameters
  - Used to automatically calculate K_e when $K_e = 0$
  - $V_r = 0$ approach → K_e is set to force $V_r = 0$ (GE PSLF)
  - $V_r > 0$ approach → K_e is set to force $V_r = V_{RMAX}/10$ (PTI PSSE)
- Machine Saturation when S12 < S10
  - This is bad data probably but you can request Simulator just flip the values
- Saturation when One SE is Zero
  - Treat always as zero, or Normal Curve Fit
- MotorW Modeling
  - Use PSLF modeling or Full Model

Transient Stability Options: Power System Model

- Governor Fast Valving Option– When to Initiate
  - After a specified frequency deviation in rad/sec
  - After a fault
  - Specified time delay in seconds
  - Do not initiate
- Ignore Speed Effects in Generator Swing Equation
  - Generator swing equation includes a term that divides the P_{mech} by the per unit speed.
  - Normally you should not ignore this effect.
- Include Undocumented Governor PI Limits
  - Some limits are undocumented and model internally in PowerWorld
- Include dynamic 3 terminal Pacific DC Intertie or Intermountain DC
  - If appropriate MTDC record exist in the case.