Transient Stability Analysis with PowerWorld Simulator

T14: Large-Scale Simulation Examples

PowerWorld Corporation

2001 South First Street
Champaign, Illinois 61820
+1 (217) 384.6330

support@powerworld.com
http://www.powerworld.com

Large Scale Simulation Examples

- We'll use an old WECC model to provide a complete example of running a stability simulation
  - Double Palo Verde Outage
  - Fault at bus
  - Fault a bus with a longer clearing time
  - Fault near a DC line Rectifier

Load Case

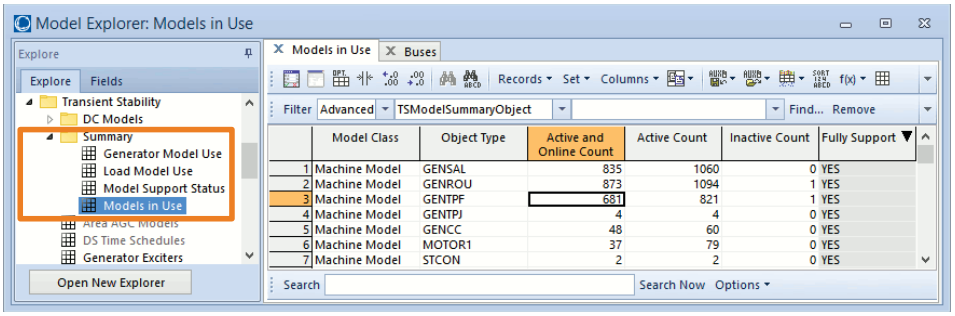
- Click the Application Menu
- Choose **Open Case…**
- Change **Files of Type** to *GE EPC Format (*.epc)*
- Navigate to choose the file *WestExample.epc*
- Click **Open**
- Click **Solve Power Flow – Newton** Button to solve initial power flow solution

Open the Stability Data

- Click the Application Menu
- Choose **Load Transient Stability Data\Load GE Data**
- Navigate to choose the file *WestExample.dyd*
- Click **Open**
- Dialog will appear asking about “Missing” models. Choose **Yes**.
- Look a log
  - GENCC models causes a new generators to be created.
  - Only 3 missing models
  - Small number of unsupported models related to DC lines, Coal Strip Acceleration Trip relay

Check Model Support

- In Model Explorer, go to **Transient Stability\Summary\Models in Use**
- Sort by **Fully Supported**. All generators models that are in use in this case are presently fully supported by Simulator.

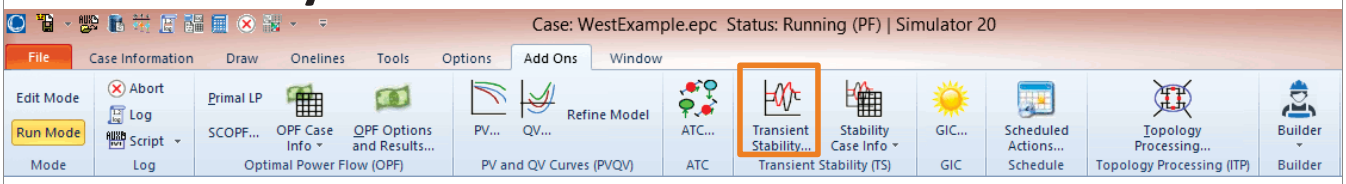


Load in Transient Contingency and Transient Options

- Click the Application Menu
- Choose **Load Auxiliary**
- Navigate to choose the file *LargeExample.aux*
- Click **Open**
- This created several Transient Contingencies
- Also loaded in some options for the stability simulation

Transient Stability Analysis Dialog

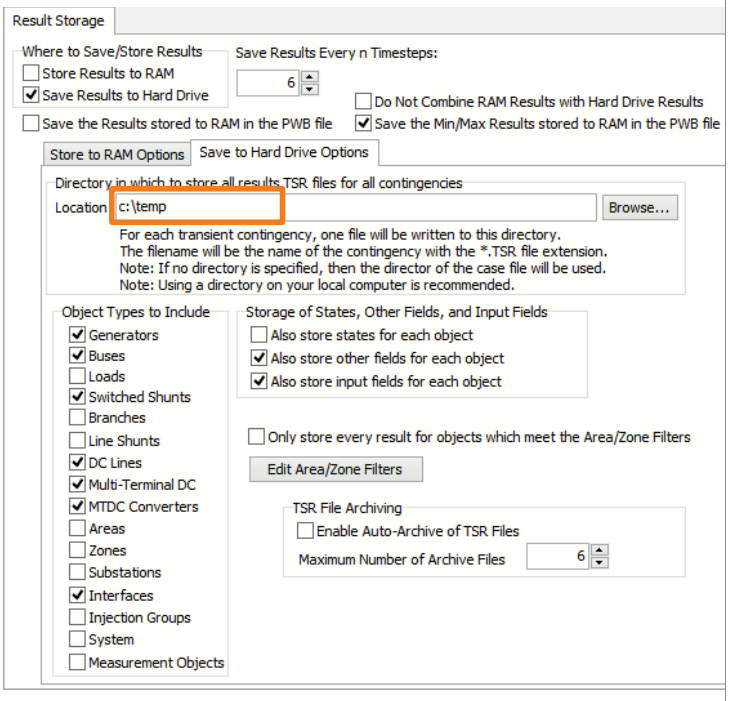
- On the Add-Ons Ribbon Tab, click **Transient Stability…**



- Run the AutoCorrection on input data
  - Go to the Validation Step
  - Click Run **AutoCorrection** button
  - Look through Informational Messages for notes about changes to time constants and machine reactances

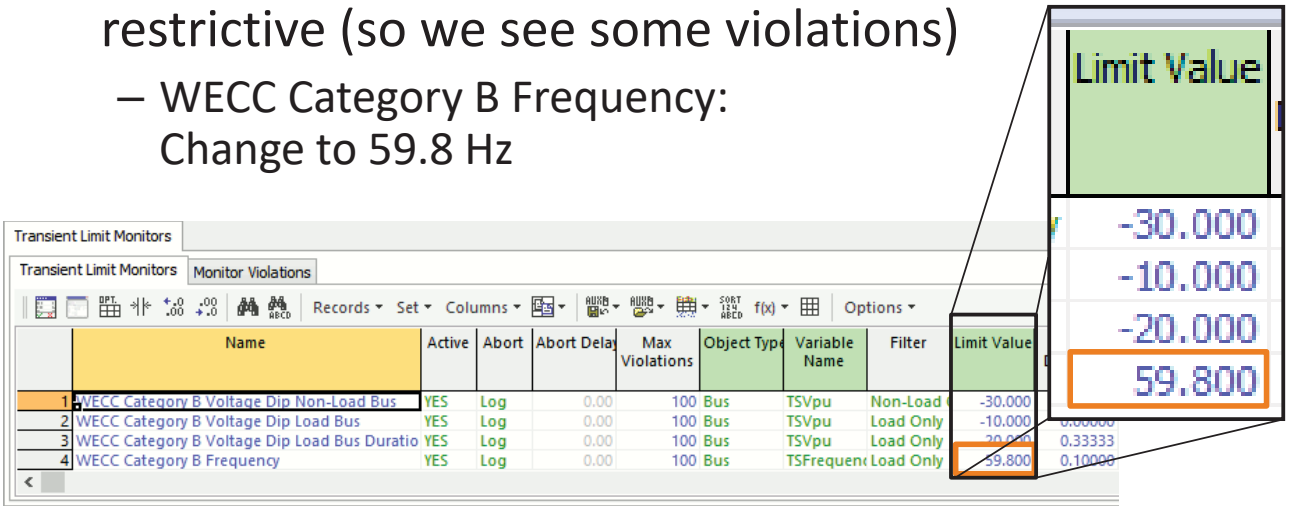
Result Storage

- Go to **Result Storage\Store to Hard Drive Options**
  - It's configured to store results to the Hard Drive every 6 time steps
  - Saves to directory location to c:\temp
    - Change this if your computer will not allow you to create a directory in c:\temp



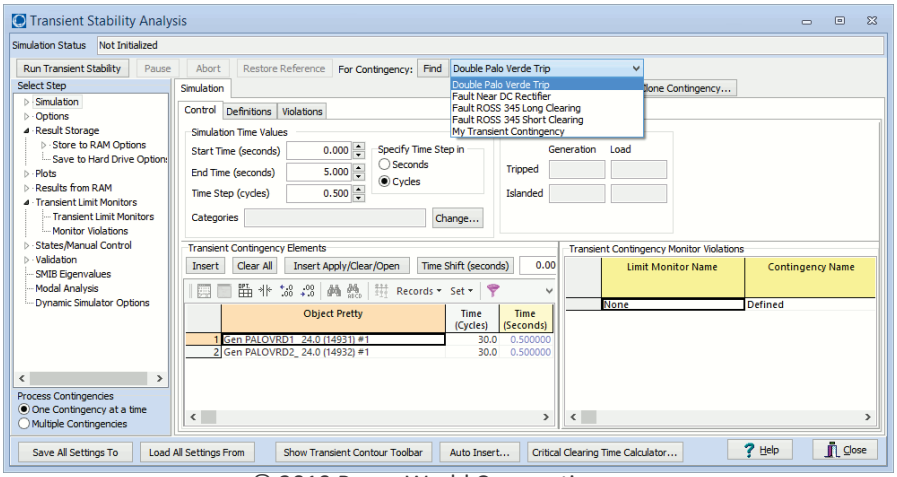
Transient Limit Monitoring

- Go to **Transient Limit Monitors**
- Toggle the **Active** column to all say *YES*
- Modify the Limit Monitors to make them more restrictive (so we see some violations)
  - WECC Category B Frequency: Change to 59.8 Hz



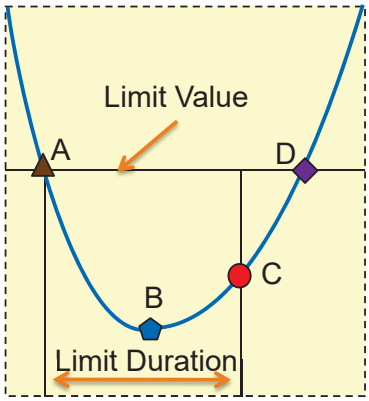
Run One Transient Contingency

- Go back to the *Simulation* Step
  - Choose the **Double Palo Verde Trip** from the **For Contingency:** listing
  - This trips two Palo Verde units at time 0.5 seconds.
- Click **Run Transient Stability**



Look at Transient Limit Monitor Violations

- Transient Limit Monitors: Monitor Violations
  - Several show values below 59.8 Hz for more than 0.1 seconds.



Transient Limit Monitors

Transient Limit Monitors | Monitor Violations

Records | Set | Columns | Options

	Limit Monitor Name	Contingency Name	Violated Device	Limit Monitor Variable	Actual Value	Time Valu	Actual Value Start	Time of Value Start	Actual Value Extreme	Time of Value Extreme	Actual Value No Longer	Time of No Longer
1	WECC Category B Frequency	Double Palo Verde Trip	Bus '54422'	TSFrequenc	59.786224	4.1250	59.799465	4.0167	59.755615	4.6417		
2	WECC Category B Frequency	Double Palo Verde Trip	Bus '54424'	TSFrequenc	59.786480	4.1250	59.799683	4.0167	59.755882	4.6417		
3	WECC Category B Frequency	Double Palo Verde Trip	Bus '54490'	TSFrequenc	59.785378	4.1250	59.798916	4.0167	59.753525	4.6417		
4	WECC Category B Frequency	Double Palo Verde Trip	Bus '54491'	TSFrequenc	59.786350	4.1250	59.799702	4.0167	59.755016	4.6417		
5	WECC Category B Frequency	Double Palo Verde Trip	Bus '54492'	TSFrequenc	59.786381	4.1250	59.799755	4.0167	59.754925	4.6417		
6	WECC Category B Frequency	Double Palo Verde Trip	Bus '56302'	TSFrequenc	59.785099	4.1250	59.799747	4.0167	59.745365	4.7250		
7	WECC Category B Frequency	Double Palo Verde Trip	Bus '56885'	TSFrequenc	59.786194	4.1250	59.799911	4.0167	59.753067	4.6500		
8	WECC Category B Frequency	Double Palo Verde Trip	Bus '57101'	TSFrequenc	59.784306	4.1250	59.799080	4.0167	59.747181	4.6667		
9	WECC Category B Frequency	Double Palo Verde Trip	Bus '58185'	TSFrequenc	59.785767	4.1250	59.799786	4.0167	59.751457	4.6583		
10	WECC Category B Frequency	Double Palo Verde Trip	Bus '59101'	TSFrequenc	59.784557	4.1250	59.799255	4.0167	59.747650	4.6667		
11	WECC Category B Frequency	Double Palo Verde Trip	Bus '59301'	TSFrequenc	59.785110	4.1250	59.799759	4.0167	59.745510	4.7167		
12	WECC Category B Frequency	Double Palo Verde Trip	Bus '54001'	TSFrequenc	59.786015	4.1333	59.799557	4.0250	59.753601	4.6583		
13	WECC Category B Frequency	Double Palo Verde Trip	Bus '54002'	TSFrequenc	59.786404	4.1333	59.799725	4.0250	59.754890	4.6500		
14	WECC Category B Frequency	Double Palo Verde Trip	Bus '54004'	TSFrequenc	59.786621	4.1333	59.799984	4.0250	59.754765	4.6583		
15	WECC Category B Frequency	Double Palo Verde Trip	Bus '54008'	TSFrequenc	59.786201	4.1333	59.799637	4.0250	59.754230	4.6583		
16	WECC Category B Frequency	Double Palo Verde Trip	Bus '54009'	TSFrequenc	59.786171	4.1333	59.799614	4.0250	59.754185	4.6583		
17	WECC Category B Frequency	Double Palo Verde Trip	Bus '54013'	TSFrequenc	59.786350	4.1333	59.799694	4.0250	59.754761	4.6583		
18	WECC Category B Frequency	Double Palo Verde Trip	Bus '54015'	TSFrequenc	59.786762	4.1333	59.799862	4.0250	59.756134	4.6500		
19	WECC Category B Frequency	Double Palo Verde Trip	Bus '54016'	TSFrequenc	59.786575	4.1333	59.799942	4.0250	59.754730	4.6583		
20	WECC Category B Frequency	Double Palo Verde Trip	Bus '54018'	TSFrequenc	59.786682	4.1333	59.799820	4.0250	59.755920	4.6500		
21	WECC Category B Frequency	Double Palo Verde Trip	Bus '54020'	TSFrequenc	59.786777	4.1333	59.799866	4.0250	59.756214	4.6500		
22	WECC Category B Frequency	Double Palo Verde Trip	Bus '54040'	TSFrequenc	59.786770	4.1333	59.799885	4.0250	59.755985	4.6500		
23	WECC Category B Frequency	Double Palo Verde Trip	Bus '54044'	TSFrequenc	59.786278	4.1333	59.799763	4.0250	59.754021	4.6583		
24	WECC Category B Frequency	Double Palo Verde Trip	Bus '54045'	TSFrequenc	59.786510	4.1333	59.799755	4.0250	59.755249	4.6500		

Transient Events

- Look at Results\Events in the Steps
- You see the two generator's opening
- Also see an Over-Excitation Relay tripping at 1.758333 seconds at a generator.

Results from RAM

Time Values | Minimum/Maximum Values | Summary | Events | Solution Details

Records | Set | Columns | f(x) | Options

Choose which Events to display by level AND Object Type. (Note: Events are still recorded and stored according to the Result Options settings. Unchecking this box only hides them in this visu

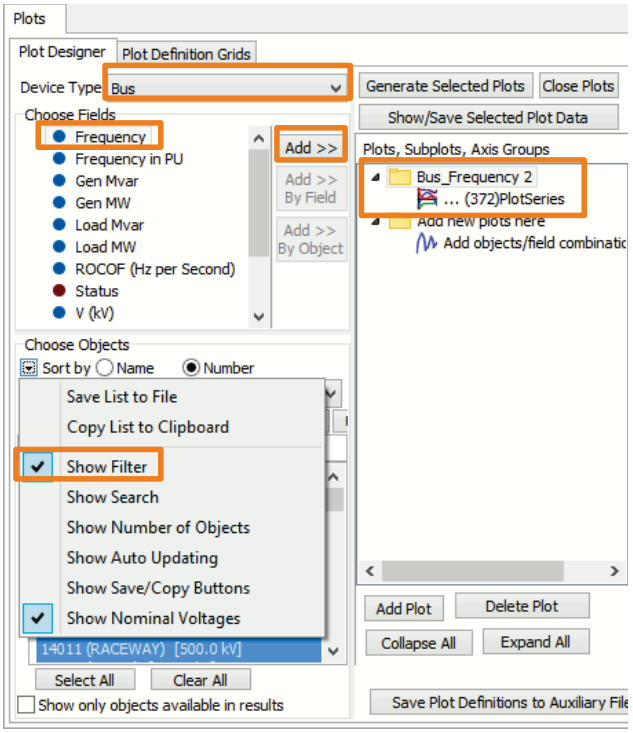
Event Levels:
- [x] Error
- [x] Info
- [x] Skipped
- [x] User
- [ ] Transition
- [x] Model Trip
- [x] Relay Trip

Object Types:
- [x] Simulation
- [x] Bus
- [x] Gen
- [x] Load

	Contingency Name	Time (Cycles)	Time (Seconds)	Object	Model Type	Description
1	Double Palo Verde Trip	30.0	0.500000	Gen '14931' '1'	TXGenericGen	Open
2	Double Palo Verde Trip	30.0	0.500000	Gen '14932' '1'	TXGenericGen	Open
3	Double Palo Verde Trip	105.5	1.758333	Gen '40344' '1'	TXGenericGen	Gen Overexcitation Relay OEL1 action: Open (TripMW=51)

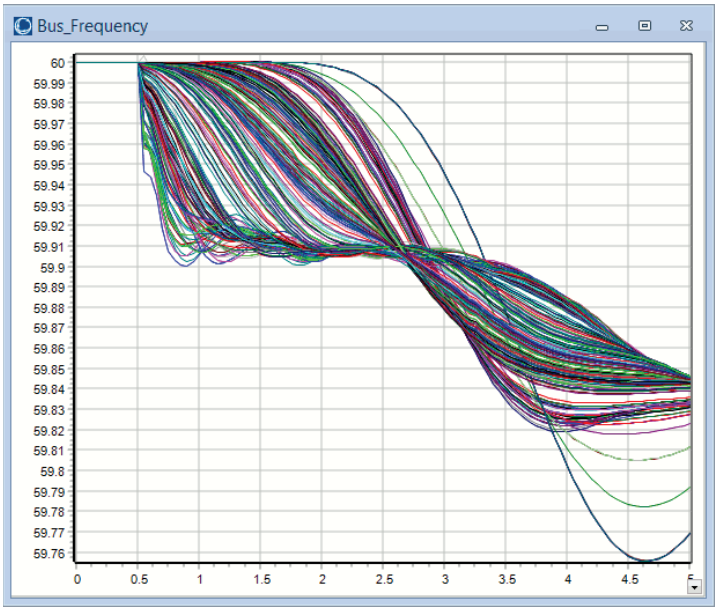
Let's create some Plots

- Go to Plots and then the Plot Designer
- Change **Device Type** to *Bus*
- **Choose Fields** = *Frequency*
- Under **Choose Objects**, right-click and choose **Show Filter**
- Click the **Define/Find…** button
- Define a filter for all buses with *Voltage\kV Nominal* greater than 400 kV and *Voltage\Per Unit Magnitude* greater than 0.1pu
- After defining the filter, click the **Select All** button
- Finally Click the **Add >>** button to define the plot (372 series)



Generate Selected Plot

- Click the **Generate Selected Plots** button
- If you run this farther out than 5 seconds you'll see it's stable

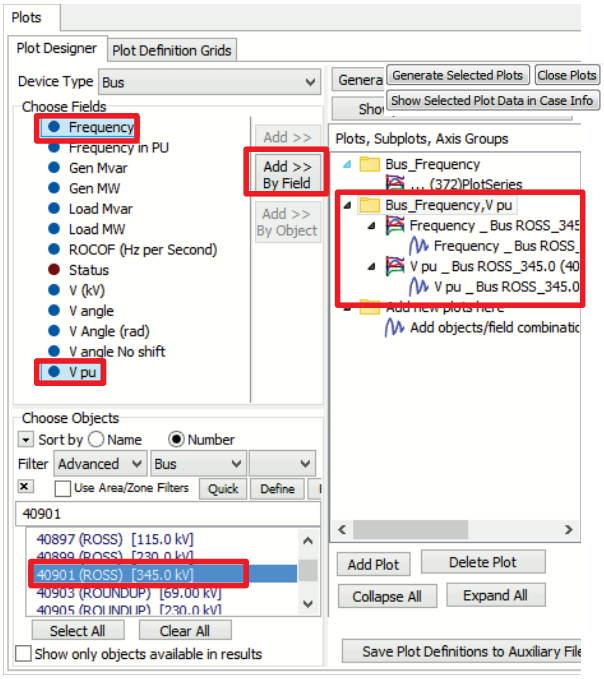


Run the two Fault ROSS Transient Contingencies

- Go back to the *Simulation* Step
  - Choose the **Fault ROSS 345 Short Clearing** from the **For Contingency:** listing
  - This fault the ROSS bus at 0.5 seconds and leaves the fault on until 0.6 seconds
  - Click **Run Transient Stability**
  - Choose the **Fault ROSS 345 Long Clearing** from the **For Contingency:** listing
  - This fault the ROSS bus at 0.5 seconds and leaves the fault on until 1.5 seconds
  - Click **Run Transient Stability**

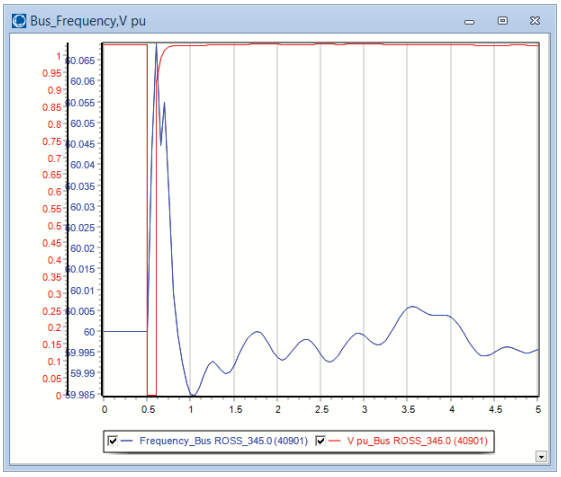
Build a Plot of the ROSS 345 Voltage and Frequency

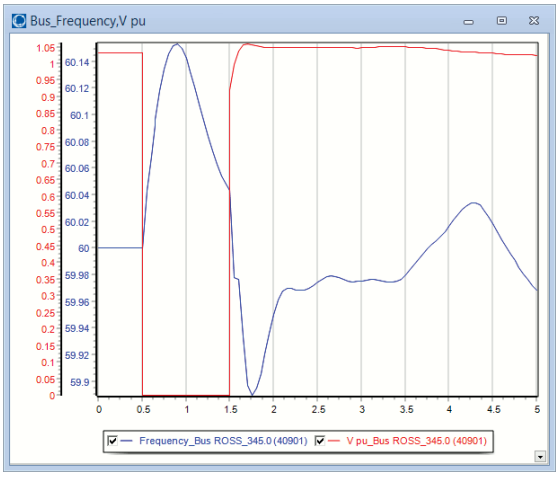
- Go to Plots and then the Plot Designer
- Change **Device Type** to *Bus*
- Hold Ctrl key and **Choose Fields** *Frequency* and *Voltage*
- Under **Choose Objects**, right-click and choose **Show Filter**
- Click the **Define/Find…** button
- Click **Remove**
- Navigate to find the ROSS 345 kV bus (40901)
- On the tree-view list of plots, choose **Add new plots here**
- Click **Add >> Group Fields**



Plots can be viewed as normal for each contingency separately

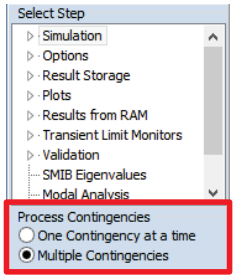
- Fault ROSS 345 Short Clearing
- Fault ROSS 345 Long Clearing

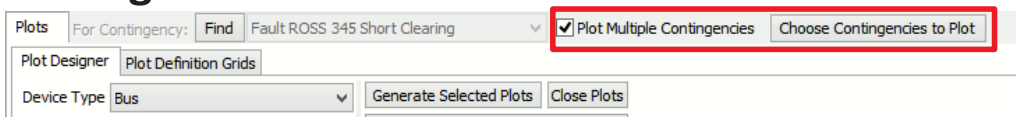




Plotting Multiple Contingencies Simultaneously

- First change the **Process Contingencies** to *Multiple Contingencies*
- Go to the Plots Step
- Check the box for **Plot Multiple Contingencies**



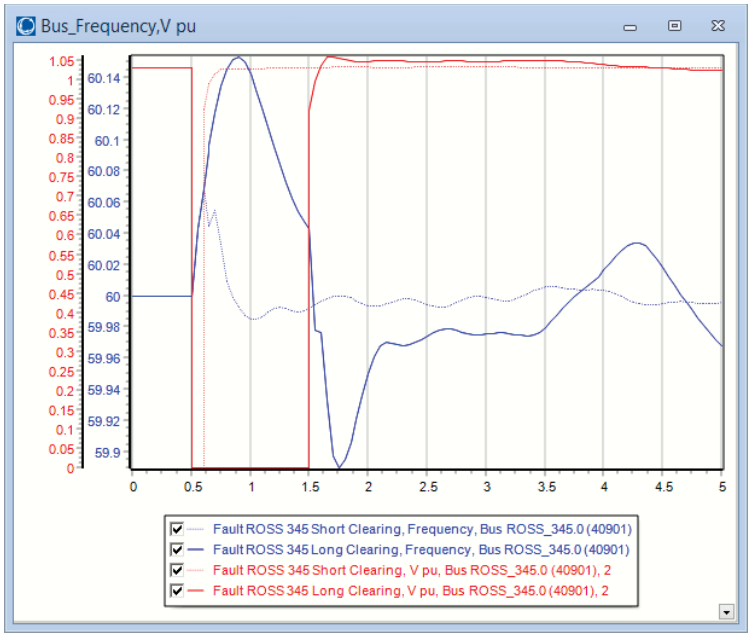


- Click **Choose Contingency to Plot**
  - Modify to only **Show** column to *YES* for only the ROSS faults
  - Change Short Clearing **Plot Dashed** to *Dot*
  - Change Long Clearing **Plot Dashed** to *Solid*

	Name	Show	Plot Color	Plot Dashed	Plot Thickness	Plot Symbol
1	My Transient Contingency	NO	Default	Default	Default	Default
2	Double Palo Verde Trip	NO	Default	Default	Default	Default
3	Fault ROSS 345 Short Clearing	YES	Default	Dot	Default	Default
4	Fault ROSS 345 Long Clearing	YES	Default	Solid	Default	Default
5	Fault Near DC Rectifier	NO	Default	Default	Default	Default

Plotting Multiple Contingencies Simultaneously

- Click the **Generate Selected Plots** button



Simulator's existing DC Transmission Model

- Last Example for today
  - Let's run a fault at the 345 kV bus MONA (65995)
  - This is near the rectifier end of the Intermountain – Adelanto DC transmission line
  - Will illustrate the present status of the DC transmission line modeling in Simulator's transient stability

DC Line Operation

- In Simulator, we presently have no dynamic DC line models
- Same Algebraic Model as used in the power flow solution is used, except for the following assumptions
  - During Transient Simulation, all DC lines operate in the constant current mode
    - Control Mode is changed to Current if it's set to Power in the initial solution
  - Transformer Taps do not change in stability
  - Dynamic Range of Alpha Assumed
    - If *Min Alpha in Power Flow* < 1
      Dynamic Min Alpha = 0
    - If *Min Alpha in Power Flow* < 6
      Dynamic Min Alpha is [*Min Alpha in Power Flow* - 1]
    - Else *Dynamic Min Alpha* = 5
  - Dynamic Range of Gamma Assumed
    - If *Min Gamma in Power Flow* < 1
      Dynamic Gamma Alpha = 0
    - If *Min Gamma in Power Flow* < 16
      Dynamic Min Gamma is [*Min Gamma in Power Flow* - 1]
    - Else *Dynamic Min Gamma* = 15

DC Line Operation

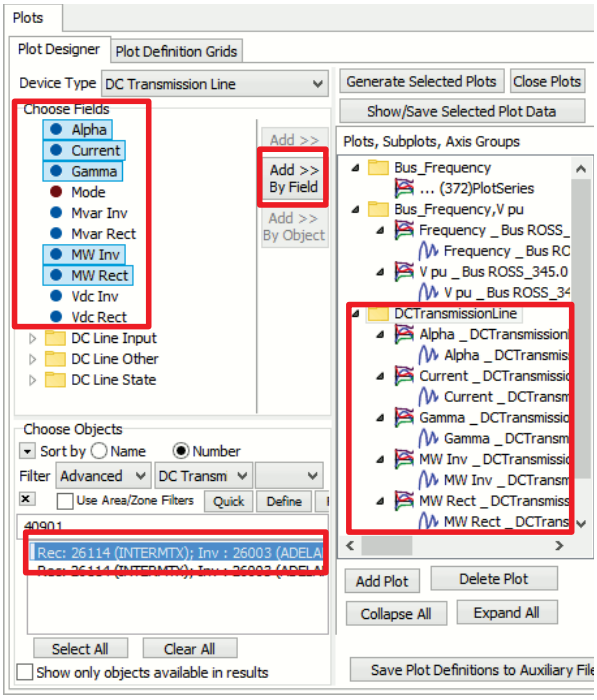
- Eventually we will need to add DC line models which reflect
  - Voltage-Dependent Current Order Limiter (VDCOL)
  - AC Voltage – Dependent Current Order Limiter
  - Dynamic states related to the measurement delay of the DC voltage and current.
  - Options to Block or Bypass the converters

Setting up Fault near DC Rectifier

- First change the **Process Contingencies** to *One Contingency at a time*
- Go back to the Simulation step
  - Choose the **Fault Near DC Rectifier** from the **For Contingency:** listing
  - This faults the MONA 345 kV bus at 0.5 seconds and leaves the fault on until 0.6 seconds
  - Click **Run Transient Stability**

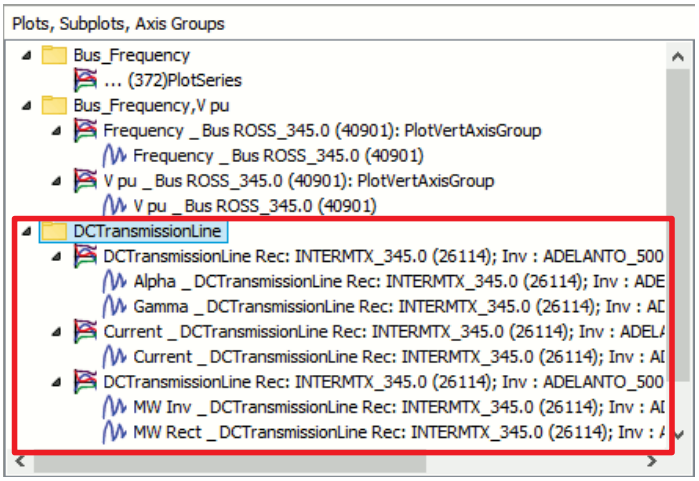
Define Plot to Illustrate DC Line Behavior

- Go to Plots and then the Plot Designer
- Change **Device Type** to *DC Transmission Line*
- Hold Ctrl key and **Choose Fields** *Alpha, Gamma, MW Rectifier, MW Inverter, DC Line Amps*
- Choose the INTERMTX – ADELANTO DC line
- On the tree-view list of plots, choose **Add new plots here**
- Click **Add >> Group Fields**



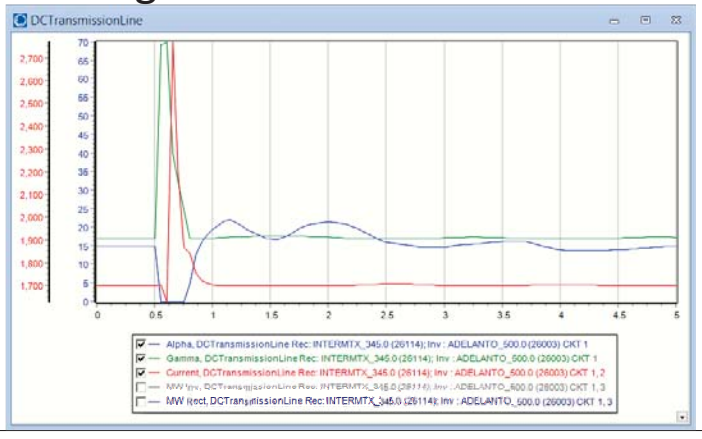
Modify Vertical Axis Groups

- Modify the Vertical Axis Groups
  - Drag the *Gamma* field to group with *Alpha*
  - Drag the *MW Rectifier* to group with *MW Inverter*
  - Delete the two empty groups
  - Click **Generate Selected Plots**



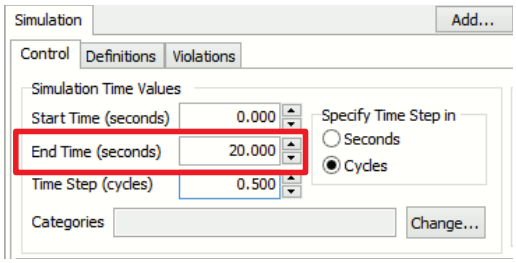
Viewing DC Line Behavior in Plot

- At the start of the fault the Alpha (Rectifier firing angle) goes to it's minimum value of 5.0 degrees
- The DC Current is reduced from 1701.3 Amps to 1541.3 Amps (a 9.4% drop)
  - Current Margin is 0.094



Final Simulation

- Go back to the Simulation step
  - Choose the **Double Palo Verde Trip** from the **For Contingency:** listing
  - Change the **End Time** to *20.00* seconds



  - Click **Run Transient Stability**

Double Palo Verde Trip
Run for 20 Seconds