Transient Stability Analysis with PowerWorld Simulator

T7: Transient Stability Plots

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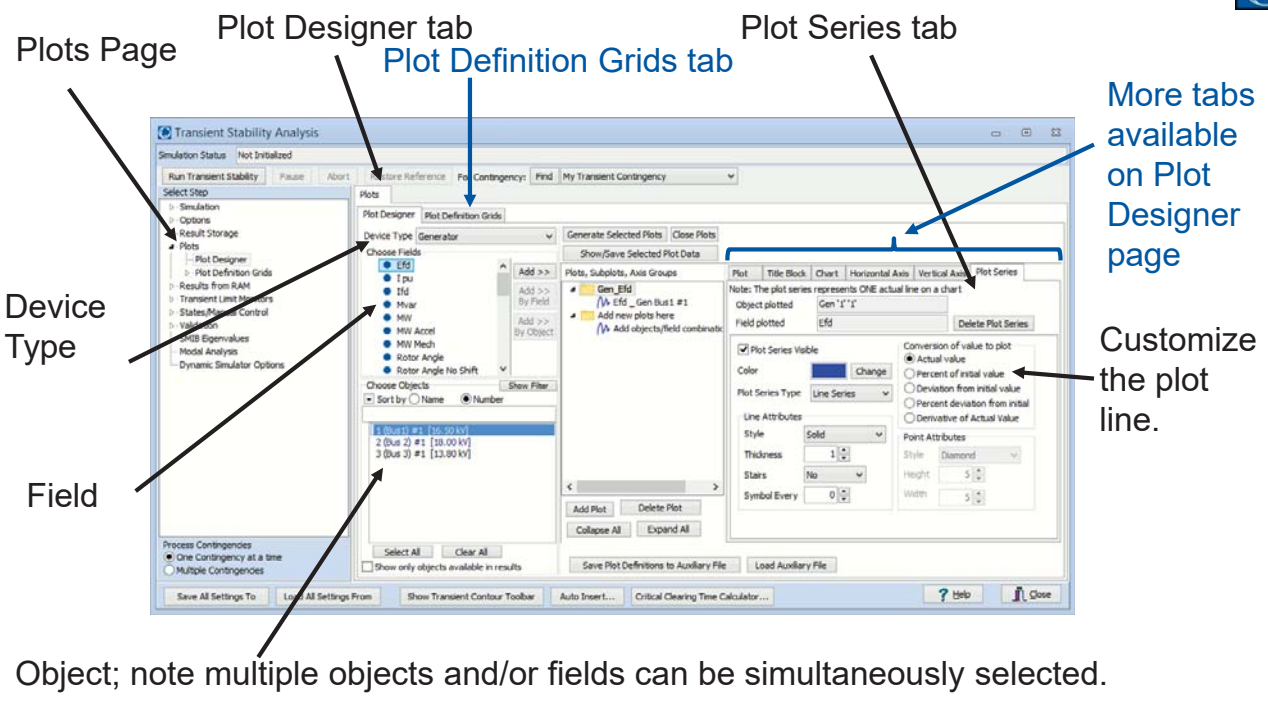
Plots

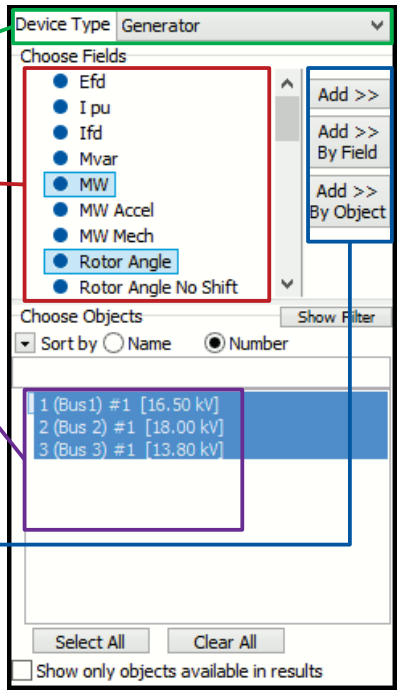
- You may design plots of data prior to performing the transient stability run. PowerWorld Simulator makes it easy to define commonly used plots.
- Simulator has been designed to give a great deal of flexibility in the design of your plots, allowing for multiple charts on a single plot, as well as multiple vertical axes on a single chart
- Plot definitions are saved with the case, and plots can be set to automatically display at the end of a transient stability run
- Any object fields in a plot definition will automatically be stored to RAM by Simulator during the run
  - Thus, you can ignore the Result Storage settings and instead just design the desired plots
  - By designing your plots, you are automatically specifying what to store
- To define plots, use the Plots page on the Transient Stability Analysis form

Defining Plots



Choosing your Plot Series

- Choosing your Plot series
  - Choose Device Type
  - Choose Multiple Fields
  - Choose Multiple Objects
- Click **Add >>** buttons
  - **Add >>**
  - **Add >> Group Fields**
  - **Add >> Group Objects**



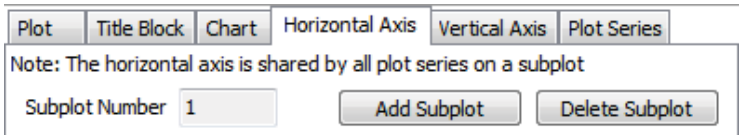
Elements of the Plot Definition

- Plot
  - A single window showing plotted results
  - A single plot can contains any number of subplots
- Subplot
  - Represents the actual graphical chart
  - Contains the horizontal axis description
  - A single subplot contains one or more axis groups
    - All the axis groups then share the horizontal axis
  - For many plots, there will only be one subplot
- Axis Groups
  - A single axis group may contain many plot series
  - Contains the vertical axis description
    - All the plot series then share the vertical axis
  - For many plots, there will only be one axis group
- Plot Series
  - Actual graphical line representing one numerical data series

Inserting and Deleting Plot Elements

- Right-Click on Plot Element to see options to Add or Delete
  - Options will be enabled based on where you right-click

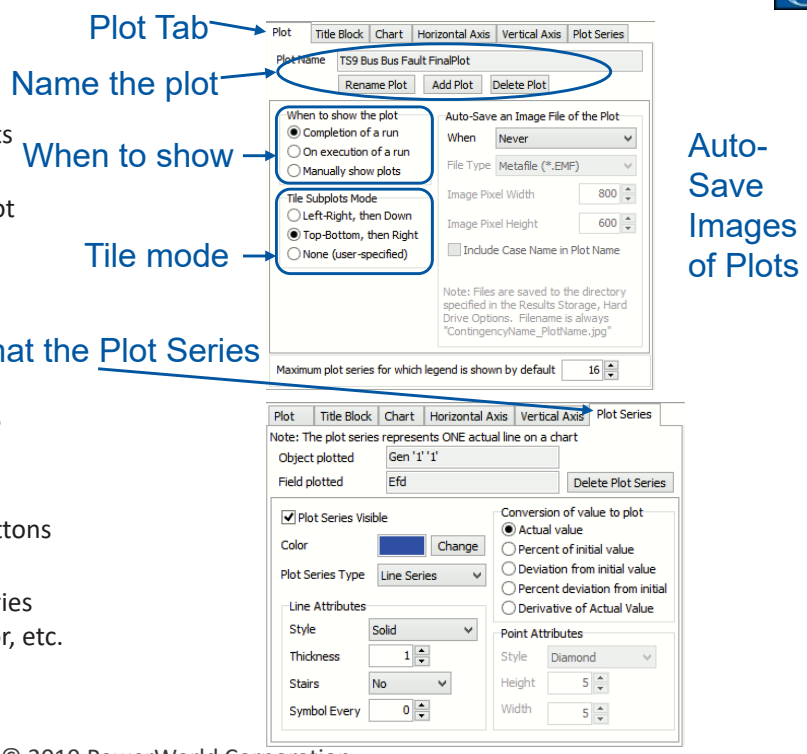
- Add and Delete buttons are on the various tabs



- Drag/Drop to move plot elements between different plots

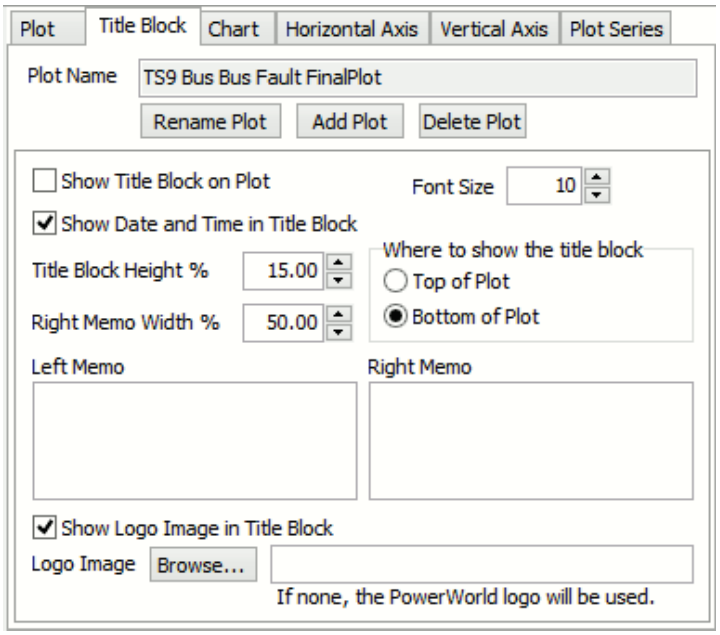
Tabs on Plot Designer Page

- Plot Tab
  - Options apply to plot
  - When to show plot
  - Options to display the subplots
- Title Block
  - Options for a title block on plot
- Chart Tab
  - Options apply to subplot
  - Background, title, footer
- Horizontal Axis Tab
  - Options apply to subplot
  - Set axis object, axis title, scale
- Vertical Axis Tab
  - Options apply to axis group
  - Axis title, scale, axis group buttons
- Plot Series Tab
  - Options apply to each plot series
  - Series line style, visibility, color, etc.



Plot Designer: Title Block

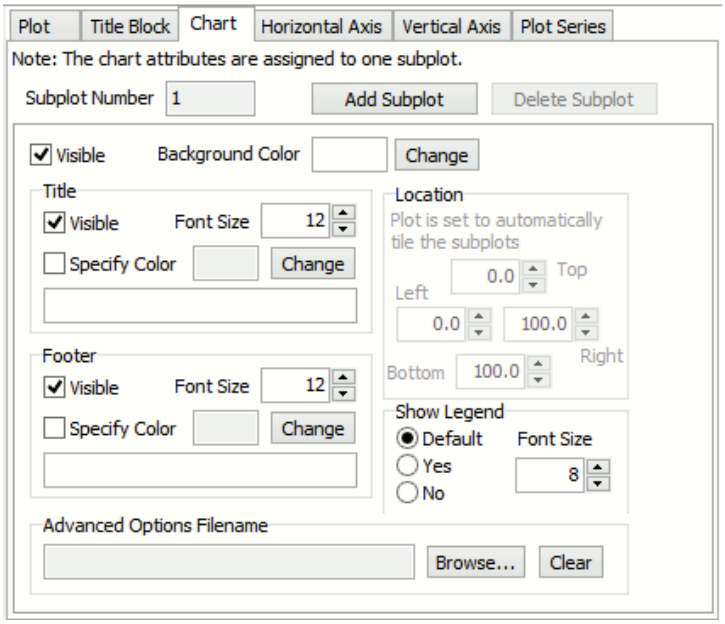
- Show
- Show Data/Time
- Sizing
- Location
  - Top/Bottom
- Font Size
- Left Memo
- Right Memo
- Show Logo
  - Custom Logo



Plot Designer: Chart Tab

- Visible
- Color
- Title, Footer
- Location
  - Used when plot is *not* set to one of the "Tile" modes
- Advanced Options
  - A file location

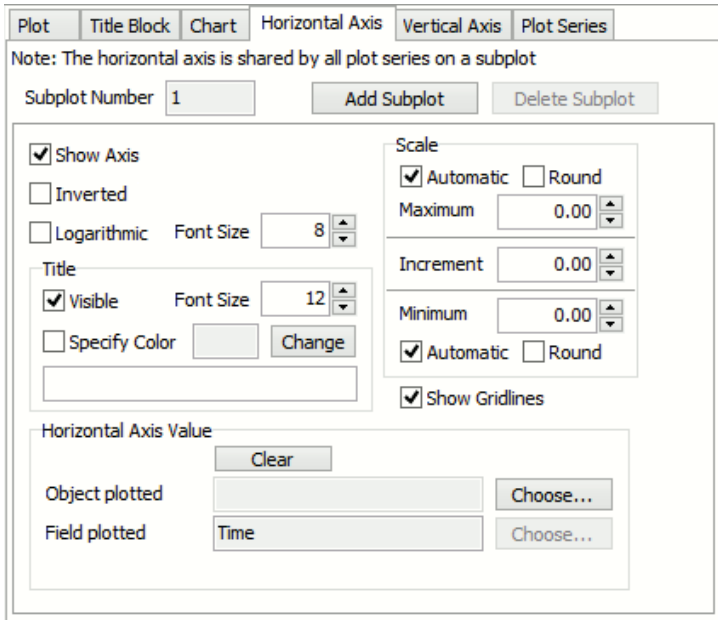
In GUI, the Subplot Number is managed internally, but when using AUX files, this is the key field for the subplot



Plot Designer: Horizontal Axis Tab

- Show Axis
- Inverted
- Logarithmic
- Title
- Scale
- Horizontal Axis Value
  - Defaults to time
  - Change for a "State Space" plot

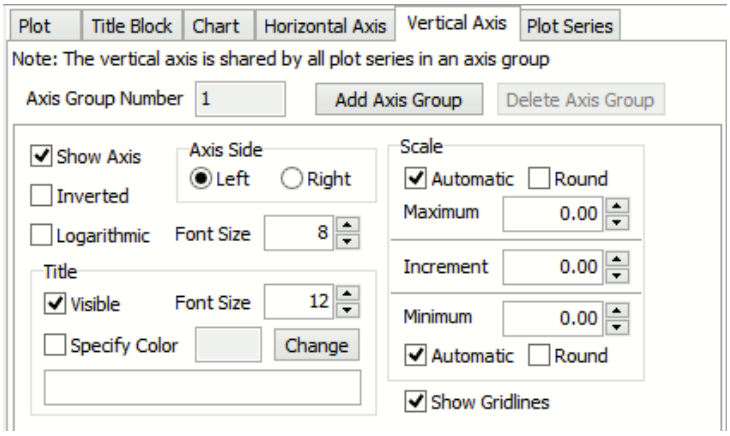
In GUI, the Subplot Number is managed internally, but when using AUX files this is the key field for the subplot



Plot Designer: Vertical Axis Tab

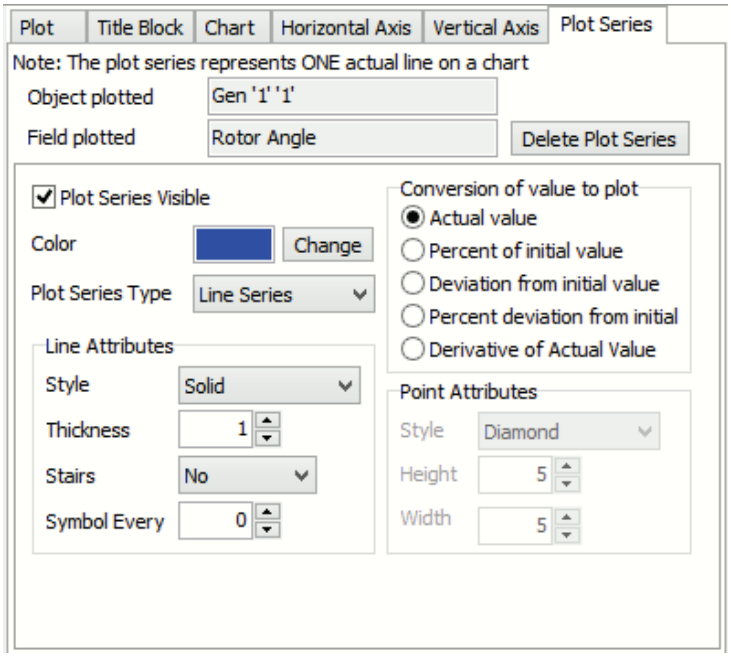
- Show Axis
- Inverted
- Logarithmic
- Title
- Scale

In GUI, the Axis Group Number is managed internally, but when using AUX files this is the key field for the axis group



Plot Designer: Plot Series Tab

- Object/Field is the key field for plot series
- Visible
- Color
- Type
  - Line Series
  - Point Series
- Line Attributes
- Point Attributes



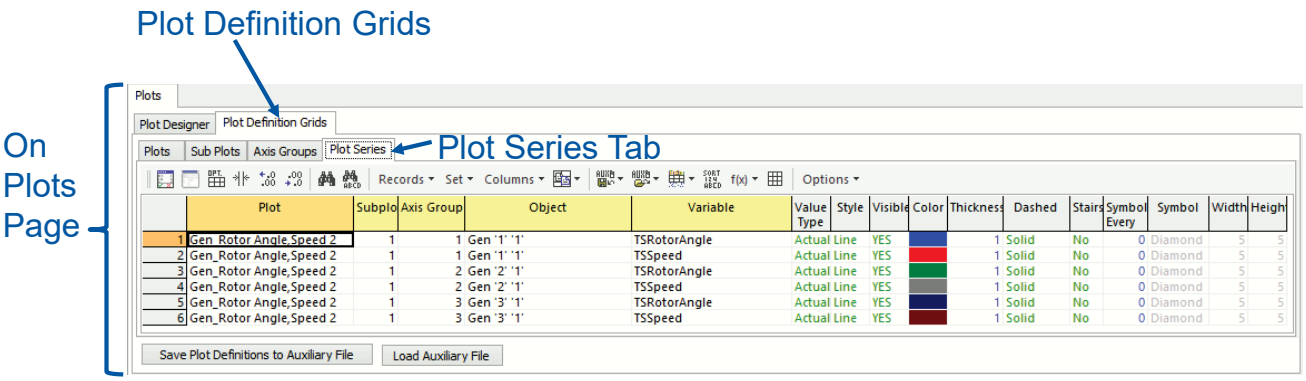
Plot Definition Grids

- Plot Definition Grids Tab appears next to Plot Designer Tab on Plots Page
- Plot Definition Grids show case information displays which provide a summary of various components comprising a plot
- Can create plots with Plot Designer and modify them using Plot Definition Grids
- Full functionality of case information displays is available
- The Plot Definition Grids provide the format for storing plot definitions in auxiliary files
- Auxiliary files of plot definitions can be saved from here

Plot Definition Grids

- Plot definition grids are case information displays which provide access to all plot elements
  - Plots
  - Sub Plots
  - Axis Groups
  - Plot Series Tab

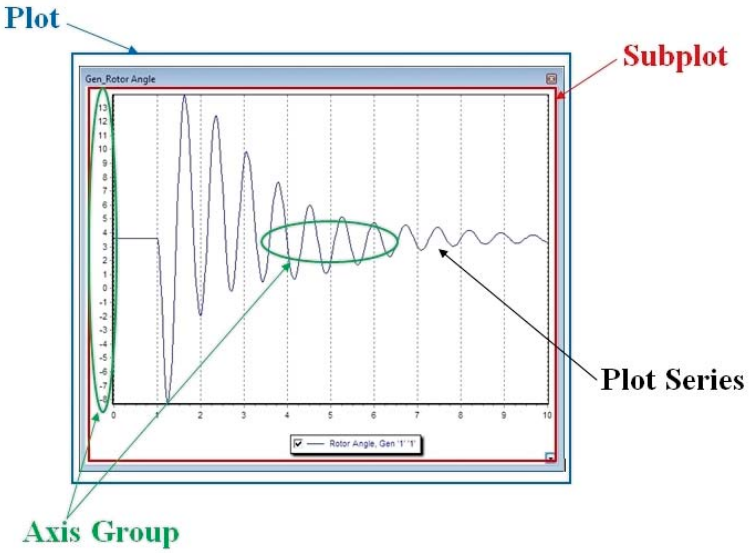
- Same information as Plot Designer, just displayed in a grid format



A Simple Plot

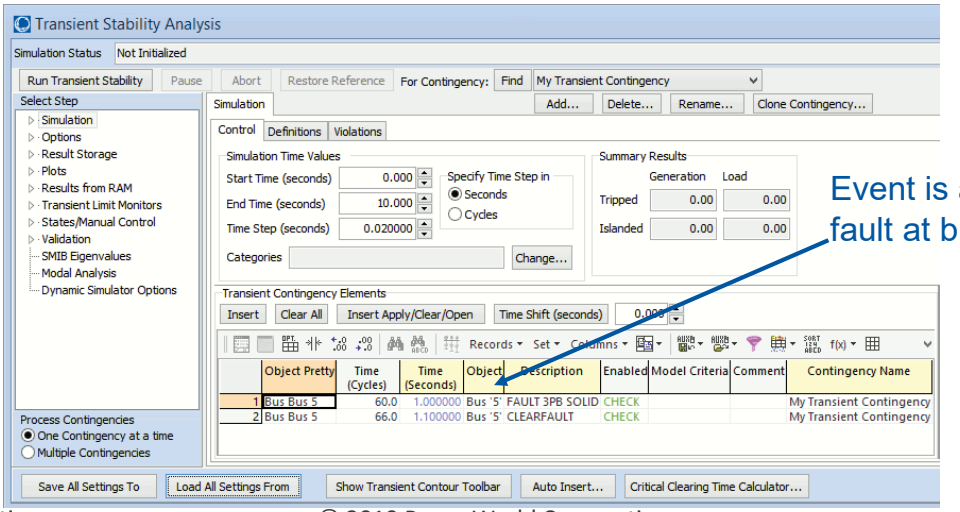
- A plot containing 1 subplot, that contains 1 axis group, that contains 1 plot series

Hierarchy:
Plot,
Subplot,
Axis group,
Plot Series



Plot Definition Example

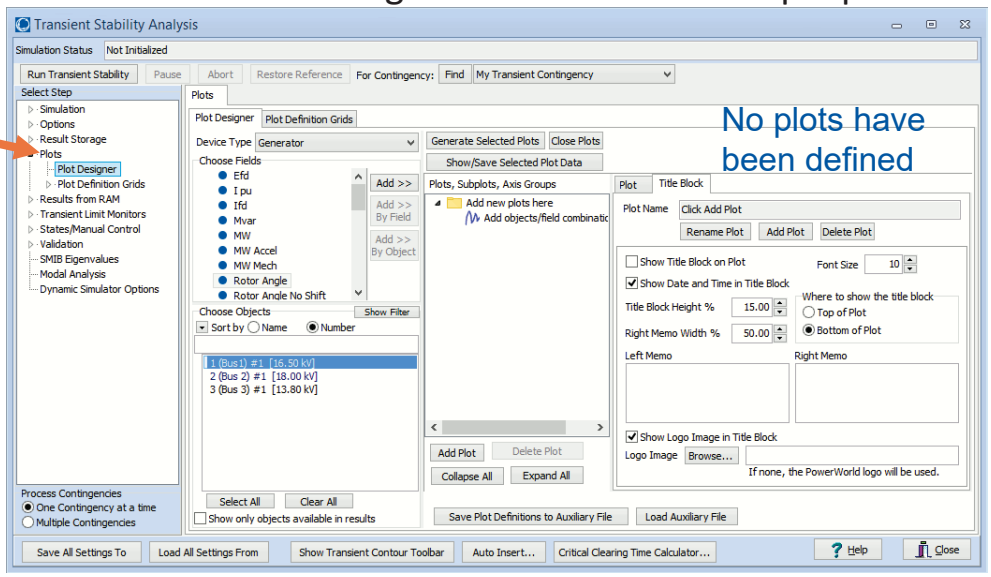
- Open "TS9Bus Bus Fault NoPlot"
- This case has GENSAL and IEEET1 models
- We will be creating some plot definitions for this system
- Open the Transient Stability Dialog



TS9Bus Bus Fault NoPlot

Example: Create a simple plot

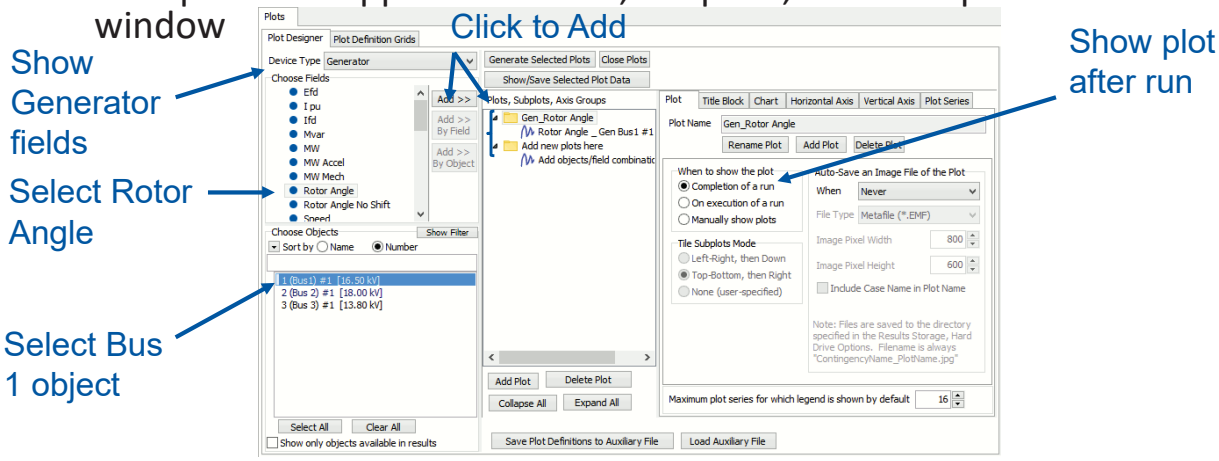
- Click “Plots” to open the Plots page
- Plot Designer Tab and Plot Definition Grids Tab are available
- We’ll use the Plot Designer Tab to create a simple plot



TS9Bus Bus Fault NoPlot

Example: Create a simple plot

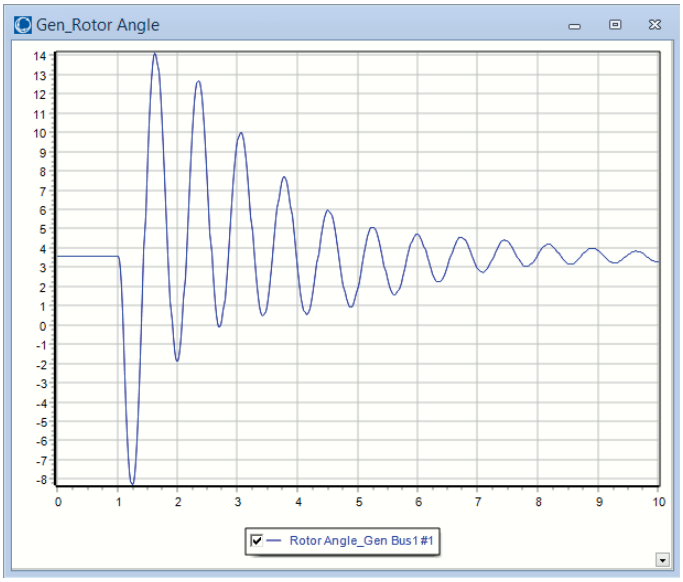
- Make a simple plot of the rotor angle of the machine at bus 1
  - Device Type- Generator
  - Fields- Rotor Angle
  - Choose Objects- Bus 1
  - Click “Add >>” Button
- New plot item appears in “Plots, Subplots, Axis Groups” window



TS9Bus Bus Fault NoPlot

Example: A simple plot

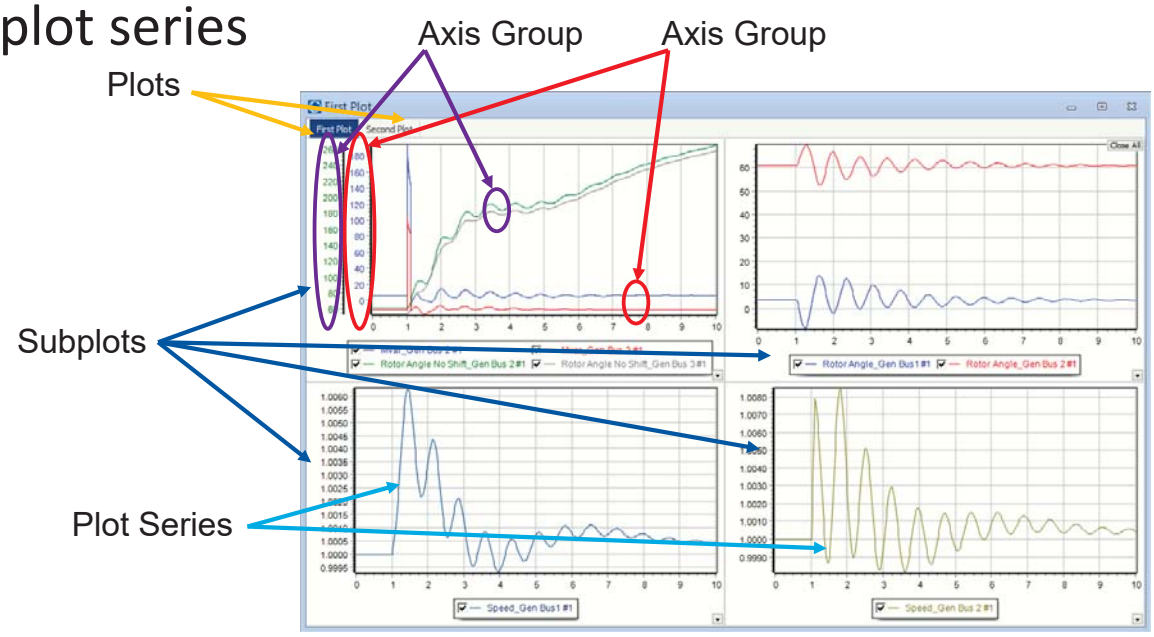
- Click “Run Transient Stability”
- A plot of the rotor angle at bus 1 is generated
- Save the case as “TS9Bus Bus Fault SimplePlot” for later use



TS9Bus Bus Fault NoPlot

A Complex Plot

- Four subplots with multiple axis groups and plot series

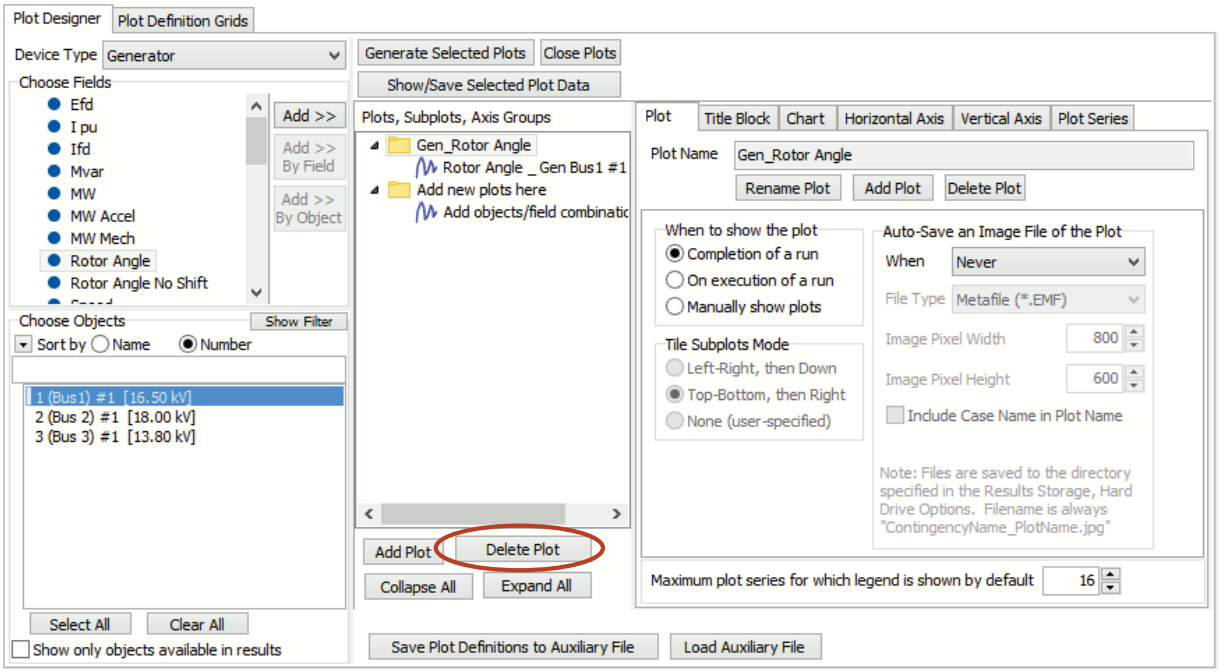


Plot Definition Example

- We will add more complex plot definitions to the current example case by implementing the following changes:
- Create 4 subplots with multiple series
- Create multiple axis groups and multiple plot series
- Change the horizontal axis variable for a subplot
  - Subplot 1- all MW Terminal series, all Rotor Angles, No Shift
  - Subplot 2- all Rotor Angle series
  - Subplot 3- all Speed series
  - Subplot 4- Speed vs. Rotor Angle of Generator 2

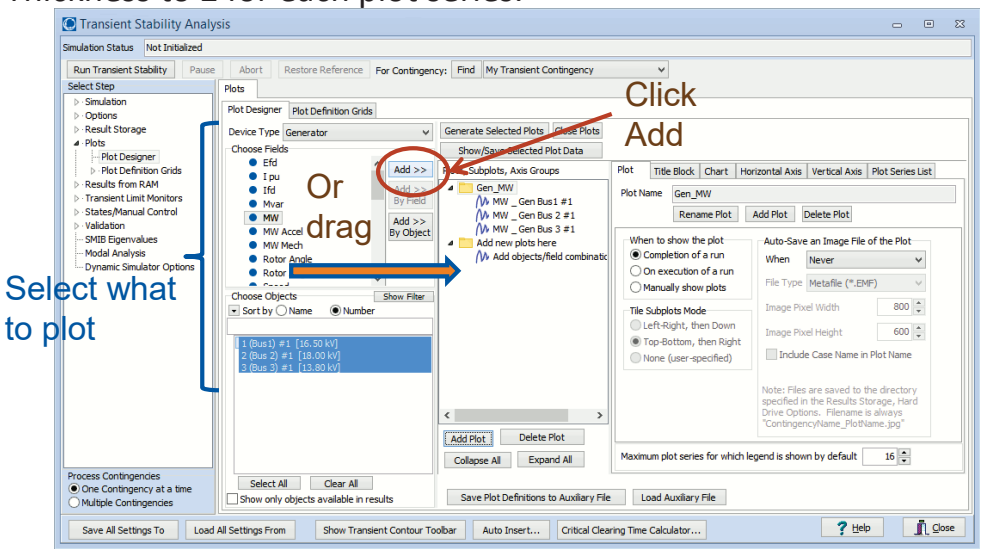
Plot Definition Example

- First, delete the existing plot by clicking the "Delete Plot" button



Plot Definition Example

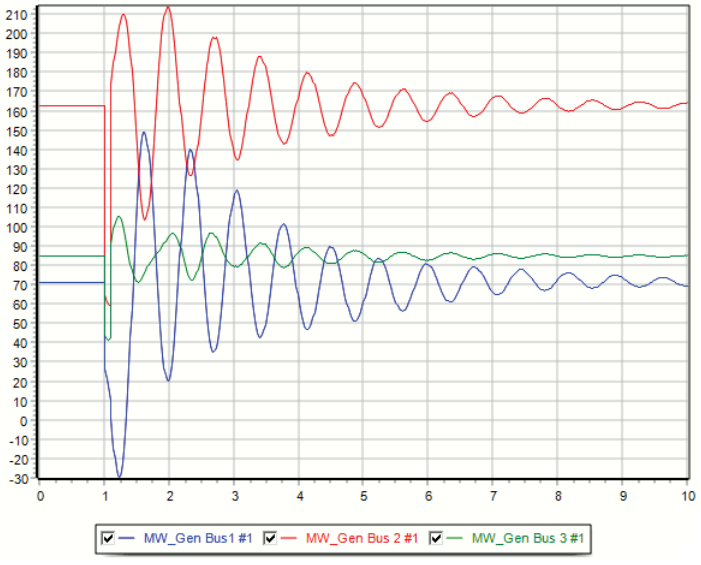
- Choose a Device Type (Generator), Field (MW Terminal), and Objects (Buses 1, 2, and 3).
- Then click the "Add" button (or drag from the field list over to the plot list).
- Next click on the Plot Series tab (far right) to customize the plot's appearance; set Thickness to 2 for each plot series.



TS9Bus Bus Fault SimplePlot

Plot Definition Example

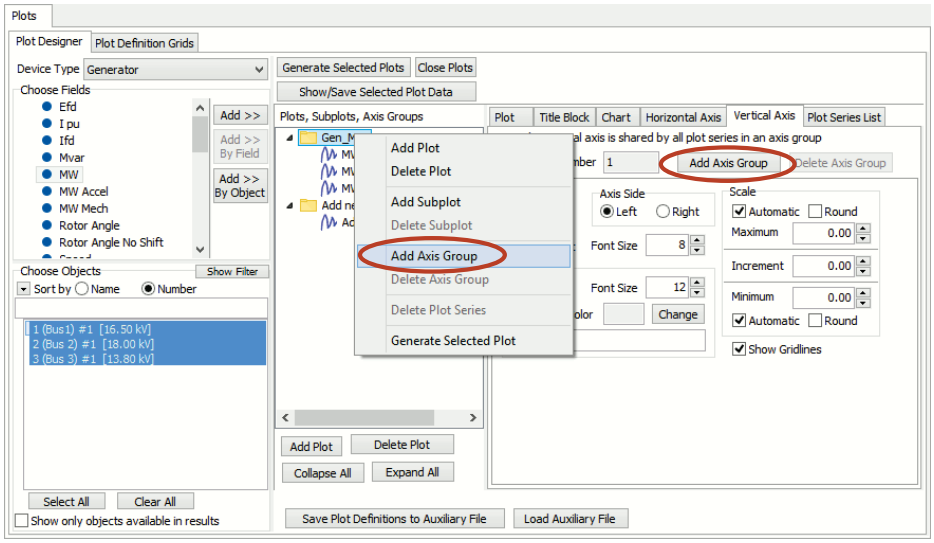
- Once the plot is designed, save the case as "TS9Bus Bus Fault Plot2" and rerun the simulation
- A single plot with three time series should now automatically appear



TS9Bus Bus Fault Plot2

Example: Add an Axis Group

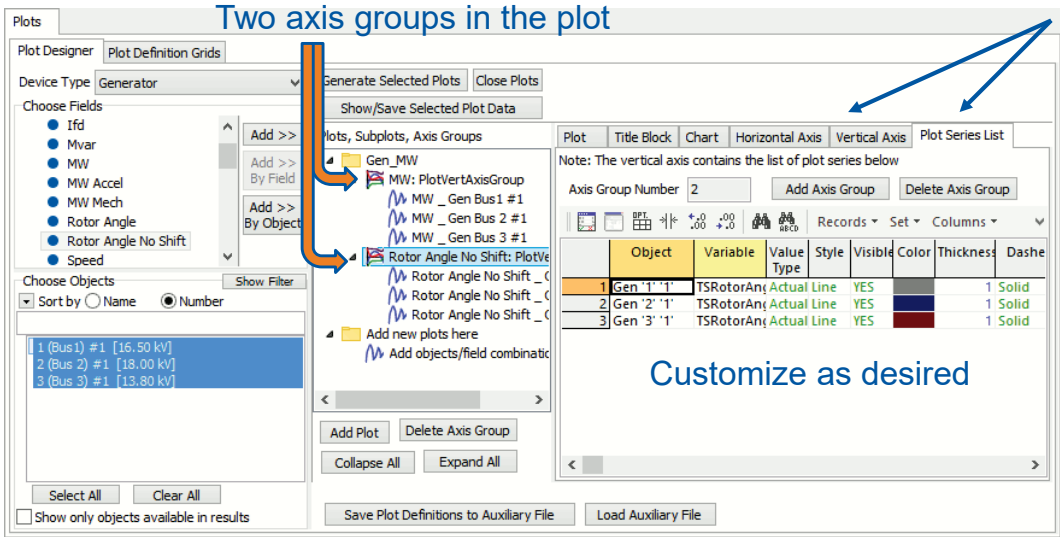
- Axis Groups are used to plot different values using different y-axes on the same plot
- This feature allows comparison of the time behavior of various fields
- Two ways to add an axis group
  - Right click on the plot series and select “Add Axis Group”
  - Select “Vertical Axis” tab and click “Add Axis Group”



TS9Bus Bus Fault Plot2

Example: Add an Axis Group

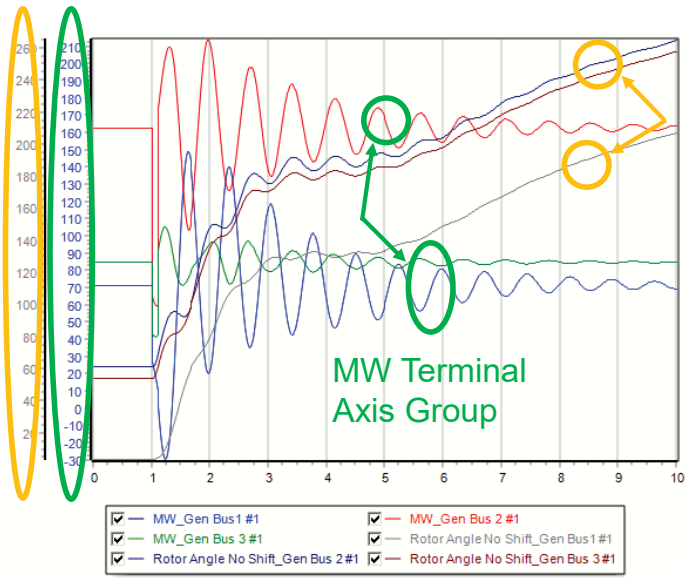
- Select the Vertical Axis tab. Then click “Add Axis Group.” Next, set the Device Type to “Generator,” the Field to “Rotor Angle, No Shift,” and select all three buses as the Objects.
- Click the “Add” button. There are now two axis groups.



TS9Bus Bus Fault Plot2

Plot Definition Example

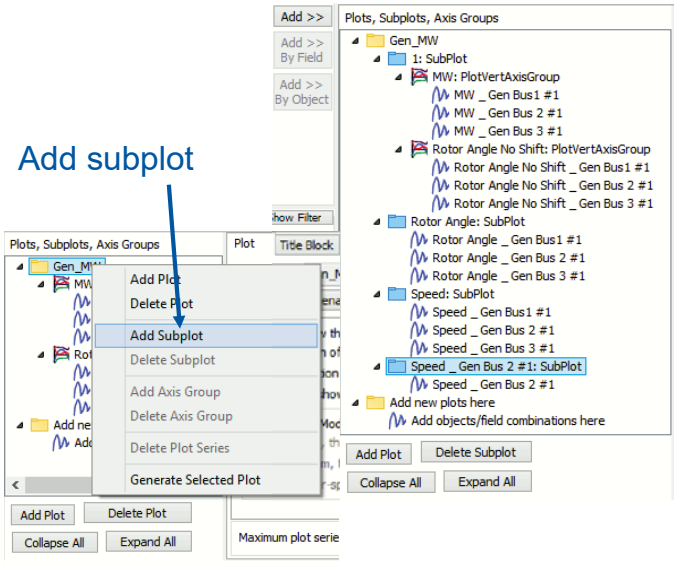
- Rerun the simulation
- A single plot with two different axis groups, each with three time series, should now automatically appear



TS9Bus Bus Fault Plot2

Example: Add Subplots

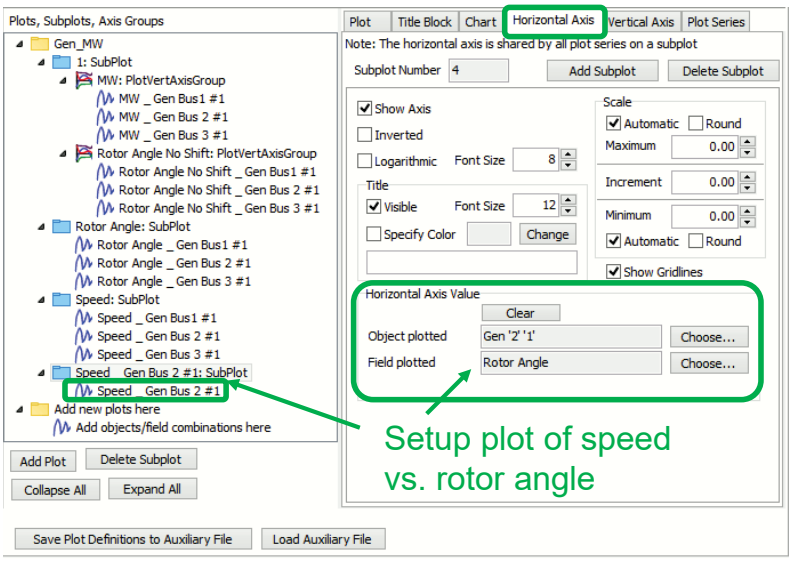
- Click “Add Subplot” three times
- Make the following subplots
  - Subplot 2- add all Rotor Angle series
  - Subplot 3- add all Speed series
  - Subplot 4- add Speed of Generator 2
- For Subplot 4, instead of plotting time on the horizontal axis, we will plot the Generator 2 rotor angle



TS9Bus Bus Fault Plot2

Example: Change Horizontal Axis Variable

- Select the fourth Subplot item, indicating the speed of Gen 2
- Select the "Horizontal Axis" tab
- On the Horizontal Axis Value Panel, we will change the "Object plotted" and "Field plotted" to Gen 2 Rotor Angle

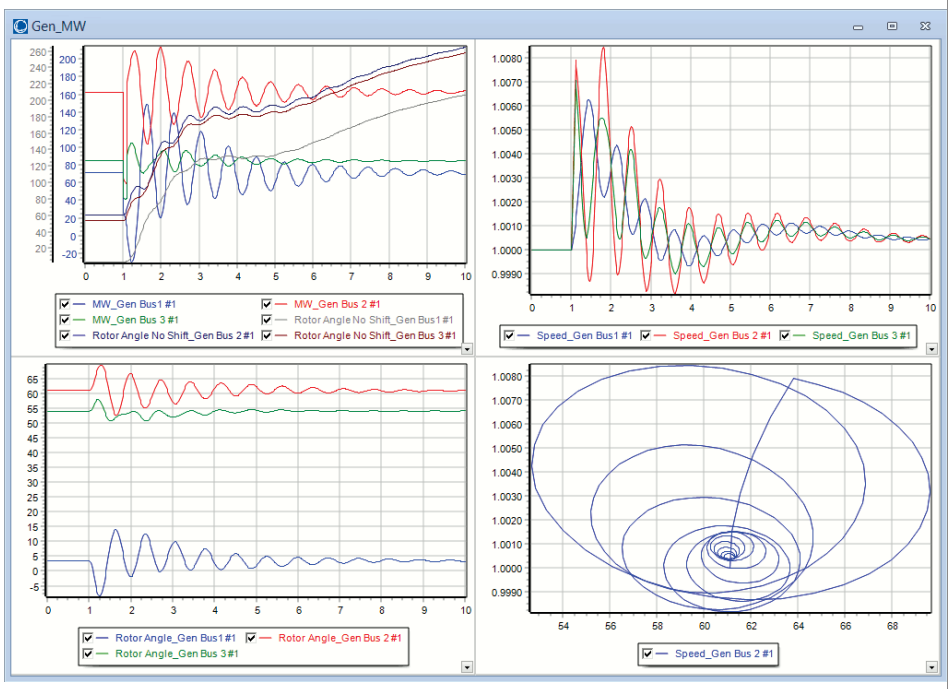


TS9Bus Bus Fault Plot2

Plot Definition Example

- Rerun the simulation
- If desired, save the case as

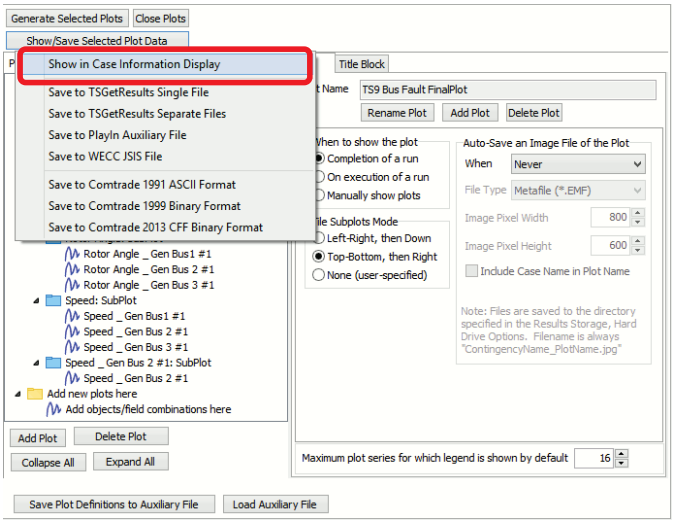
"TS9Bus Bus Fault Final Plot"



TS9Bus Bus Fault FinalPlot

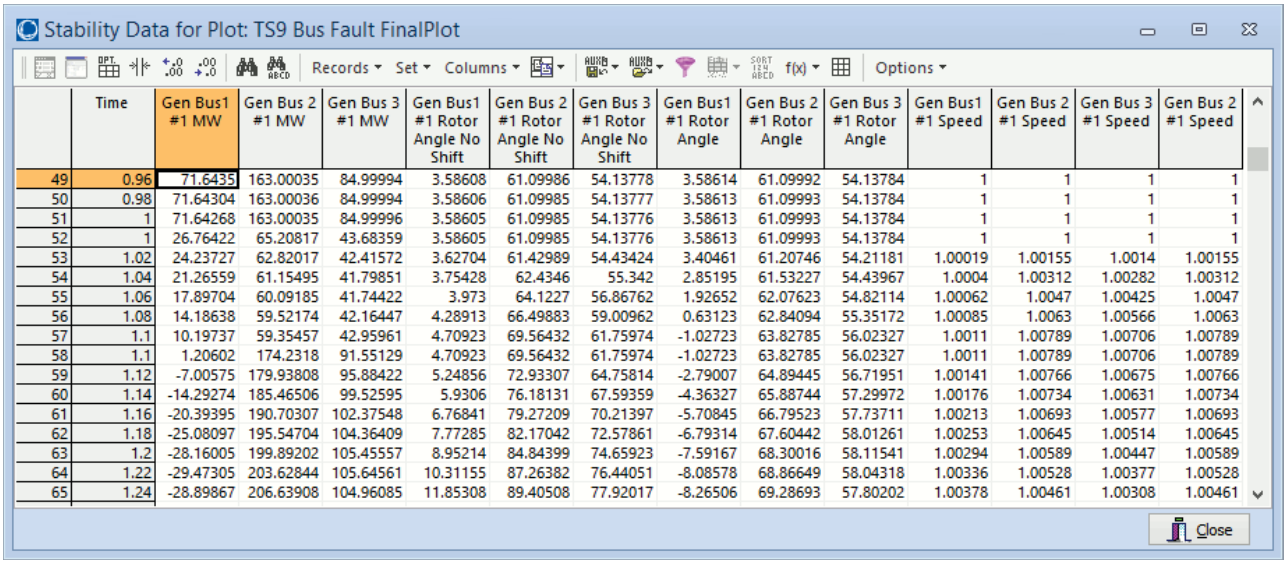
Using Plot Definitions to Design a Case Information Display

- Ultimately, the plot definition defines a list of plot series to show on the chart.
- Each plot series specifies a particular field for a particular object
- The time values for these plot series can be displayed
- Click the **Show/Save Selected Plot Data** and then **Show in Case information Display**



Show Selected Plot Data in Case Info

- Columns show the data relevant to the selected plot



	Time	Gen Bus1 #1 MW	Gen Bus 2 #1 MW	Gen Bus 3 #1 MW	Gen Bus1 #1 Rotor Angle No Shift	Gen Bus 2 #1 Rotor Angle No Shift	Gen Bus 3 #1 Rotor Angle No Shift	Gen Bus1 #1 Rotor Angle	Gen Bus 2 #1 Rotor Angle	Gen Bus 3 #1 Rotor Angle	Gen Bus1 #1 Speed	Gen Bus 2 #1 Speed	Gen Bus 3 #1 Speed	Gen Bus 2 #1 Speed
49	0.96	71.6435	163.00035	84.99994	3.58608	61.09986	54.13778	3.58614	61.09992	54.13784	1	1	1	1
50	0.98	71.64304	163.00036	84.99994	3.58606	61.09985	54.13777	3.58613	61.09993	54.13784	1	1	1	1
51	1	71.64268	163.00035	84.99996	3.58605	61.09985	54.13776	3.58613	61.09993	54.13784	1	1	1	1
52	1	26.76422	65.20817	43.68359	3.58605	61.09985	54.13776	3.58613	61.09993	54.13784	1	1	1	1
53	1.02	24.23727	62.82017	42.41572	3.62704	61.42989	54.43424	3.40461	61.20746	54.21181	1.00019	1.00155	1.0014	1.00155
54	1.04	21.26559	61.15495	41.79851	3.75428	62.4346	55.342	2.85195	61.53227	54.43967	1.0004	1.00312	1.00282	1.00312
55	1.06	17.89704	60.09185	41.74422	3.973	64.1227	56.86762	1.92652	62.07623	54.82114	1.00062	1.0047	1.00425	1.0047
56	1.08	14.18638	59.52174	42.16447	4.28913	66.49883	59.00962	0.63123	62.84094	55.35172	1.00085	1.0063	1.00566	1.0063
57	1.1	10.19737	59.35457	42.95961	4.70923	69.56432	61.75974	-1.02723	63.82785	56.02327	1.0011	1.00789	1.00706	1.00789
58	1.1	1.20602	174.2318	91.55129	4.70923	69.56432	61.75974	-1.02723	63.82785	56.02327	1.0011	1.00789	1.00706	1.00789
59	1.12	-7.00575	179.93808	95.88422	5.24856	72.93307	64.75814	-2.79007	64.89445	56.71951	1.00141	1.00766	1.00675	1.00766
60	1.14	-14.29274	185.46506	99.52595	5.9306	76.18131	67.59359	-4.36327	65.88744	57.29972	1.00176	1.00734	1.00631	1.00734
61	1.16	-20.39395	190.70307	102.37548	6.76841	79.27209	70.21397	-5.70845	66.79523	57.73711	1.00213	1.00693	1.00577	1.00693
62	1.18	-25.08097	195.54704	104.36409	7.77285	82.17042	72.57861	-6.79314	67.60442	58.01261	1.00253	1.00645	1.00514	1.00645
63	1.2	-28.16005	199.89202	105.45557	8.95214	84.84399	74.65923	-7.59167	68.30016	58.11541	1.00294	1.00589	1.00447	1.00589
64	1.22	-29.47305	203.62844	105.64561	10.31155	87.26382	76.44051	-8.08578	68.86649	58.04318	1.00336	1.00528	1.00377	1.00528
65	1.24	-28.89867	206.63908	104.96085	11.85308	89.40508	77.92017	-8.26506	69.28693	57.80202	1.00378	1.00461	1.00308	1.00461

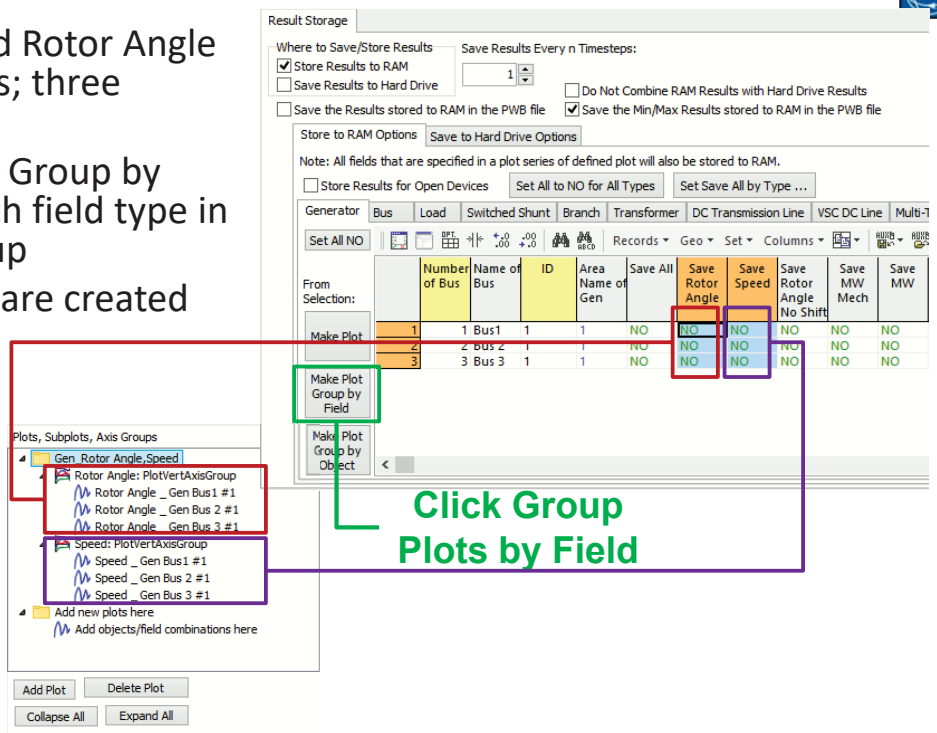
Create Plot Definitions from Results to Save Grids

- Plot Definitions can be created from “Results to Save” grids
  - Select objects (rows)
  - Select fields (columns)
  - Choose Make Plot
    - Make Plot – everything plotted on same axis group
    - Group by Field – each field on different axis group
    - Group by Object – each object on different axis group

- Open “TS9 Bus Bus Fault NoPlot”
- Open the Transient Stability Analysis dialog to the Result Storage page
- Click “Set All to NO for All Types”
- Move the Speed column next to the Rotor Angle Column

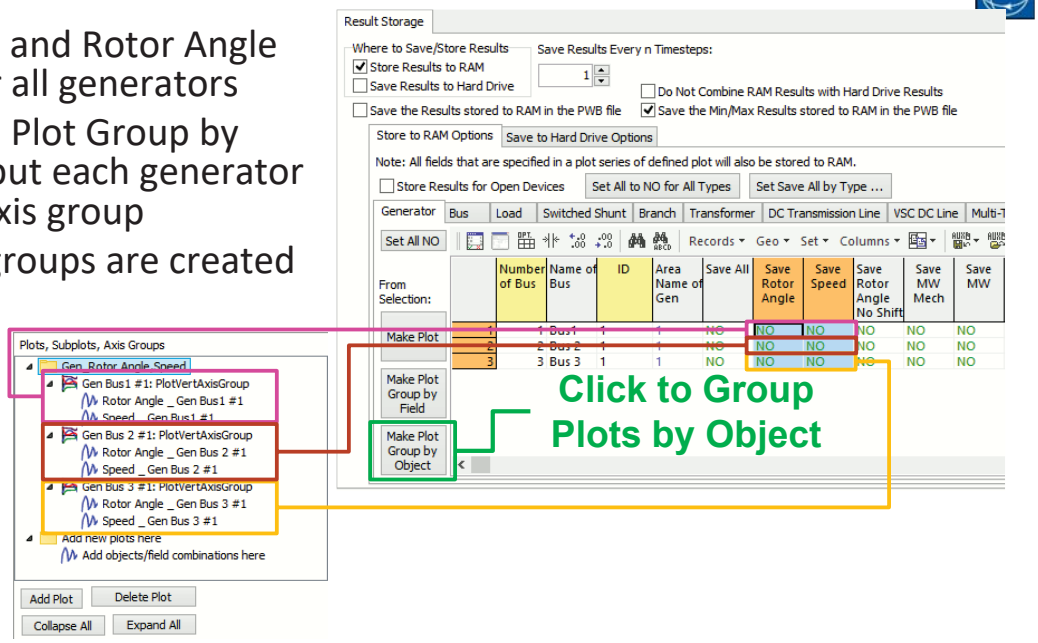
Example: Plot Definitions from Results to Save Grids

- Select Speed and Rotor Angle for all generators; three options appear
- Click “Make Plot Group by Field” to put each field type in its own axis group
- Two axis groups are created



Example: Plot Definitions from Results to Save Grids

- Keep Speed and Rotor Angle selected for all generators
- Click “Make Plot Group by Object” to put each generator in its own axis group
- Three axis groups are created



TS9Bus Bus Fault NoPlot

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