Transient Stability Analysis with PowerWorld Simulator

T10: Transient Limit Monitors

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Traditional Transient Stability Analysis

- For decades, transient stability analysis has consisted of the following general steps
  - 1. Setup a stability run
  - 2. Save results to a file – a really large file
  - 3. Query the results through the use of plots and other post-processing to determine if any reliability criteria were violated.
    - PowerWorld Simulator supports this through Results Storage to RAM and to Storage to Hard Drive as well as the integrated plotting tools

Pros and Cons

- Pros
  - All the results are available in your results files to look at later
  - Plots reaffirm that the software (and you) are doing something
  - Plots are needed for displaying your results when violations occur
- Cons
  - Storing all these results can get a little large extreme
  - What if we run 1000 stability runs?
    - Terabit hard-drives
  - Reduce storage by only saving results every 10 time-steps
    - May miss something
    - Frequency dip for only 2 time steps may be missed.

Analogy to Contingency Analysis

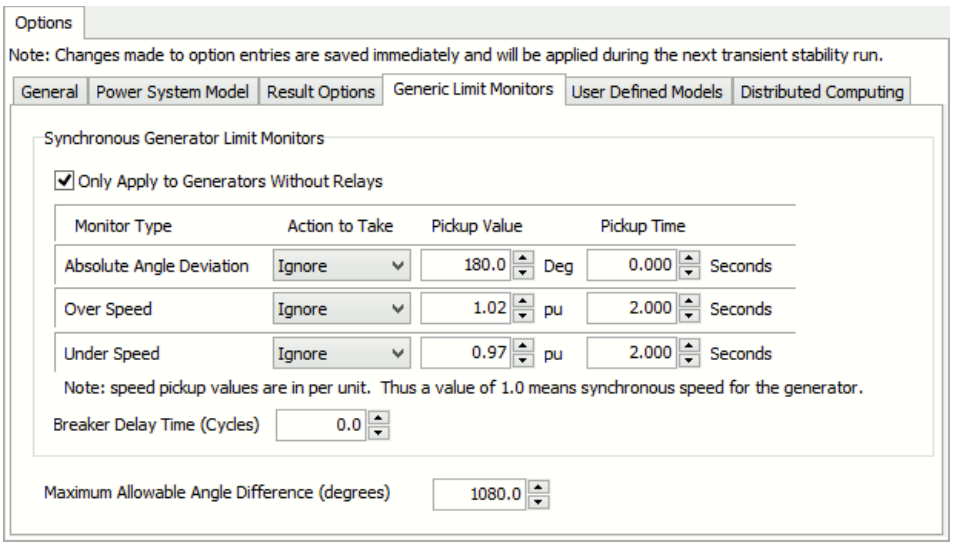
- Keeping all these results is like storing every branch flow and every bus voltage for every contingency solution
- Is this really necessary?
- Alternative: run transient stability and only store violations (like contingency analysis)
  - Options: Generic Limit Monitors
  - Transient Limit Monitors

Generic Limit Monitors: Synchronous Generators

- Synchronous Generators Limit Monitors
  - **Absolute Angle Deviation**
    - Monitors change in rotor angle change relative to initial rotor angle
    - Crude attempt to monitor for out-of-step generators
  - **Over Frequency Action**
    - Monitors high bus frequency
  - **Under Frequency**
    - Monitors low bus frequency
  - Can specify that they not be applied to generators which already have relay models

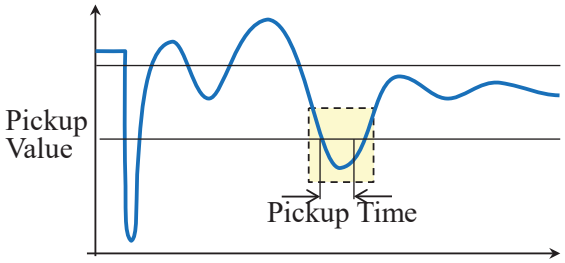
Generic Limit Monitors

- Available under Options\Generic Limit Monitors



Generic Limit Monitors: Action to Take

- **Pickup Value, Pickup Time**
  - For Under Frequency, value must fall below the pickup value and stay below the pickup value for a during of Pickup Time
  - For Over Frequency and Absolute Angle Deviation are same except they must go above the pickup value.
  - This will cause the monitor to be violated and the **Action to Take** will be used

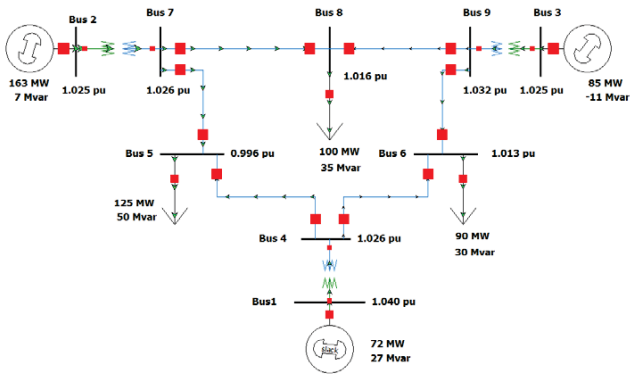


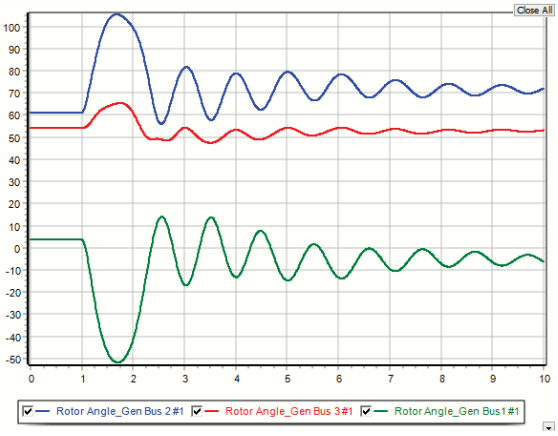
Generic Limit Monitors: Action to Take

- **Action to Take**
  - *Ignore*
    - Don't do anything. Disable the Monitor.
    - Default for Absolute Angle Deviation monitor
    - Default for Over Frequency and Under Frequency monitors for systems smaller than 100 buses
  - *Log Warning*
    - Will create an Event in the Transient Stability Results indicating that a violation occurred and when it occurred
  - *Trip*
    - Will cause the generator to trip after a time delay specified by **Breaker Delay Time**
    - Default for Over Frequency and Under Frequency for system larger than or equal to 100 buses
  - *Abort*
    - Will immediately abort the simulation

Example: Generic Limit Monitors

Open "WSCC_9Bus"

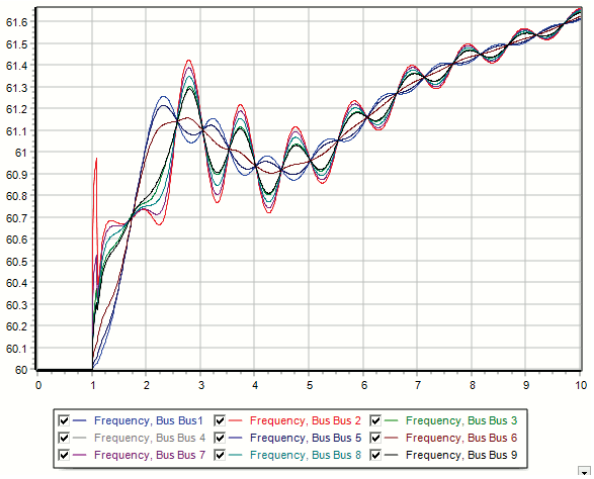


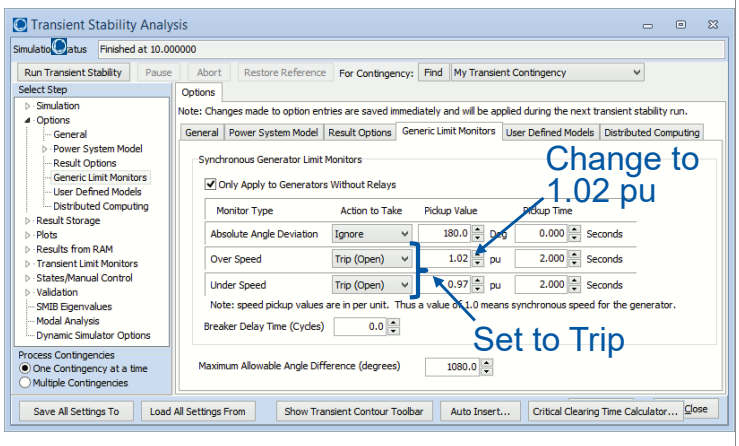


The left figure shows the initial power flow solution for the WSCC 9 bus case. The right figure shows the generator angles for a fault on the line between buses 5 and 7 near the bus 7 terminal, which is cleared after 0.077 seconds by opening the bus 5 to 7 line. Change the fault clearing time to verify that system loses stability for a clearing time between 0.079 and 0.08. This fault and the associated plots are already set up in the case, starting with a clearing at 0.077 seconds.

WSCC_9Bus

Example: Generic Limit Monitors

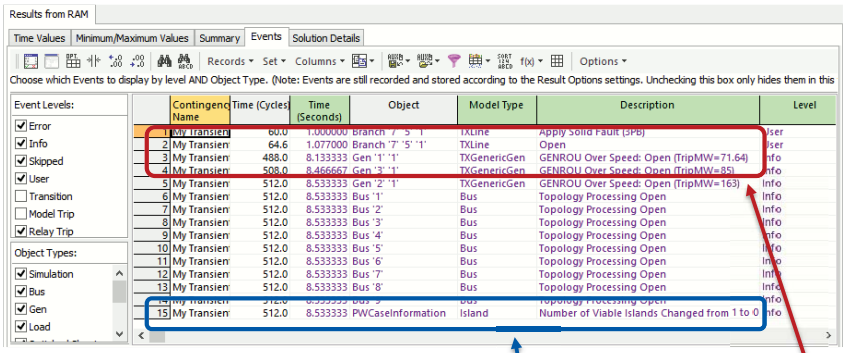


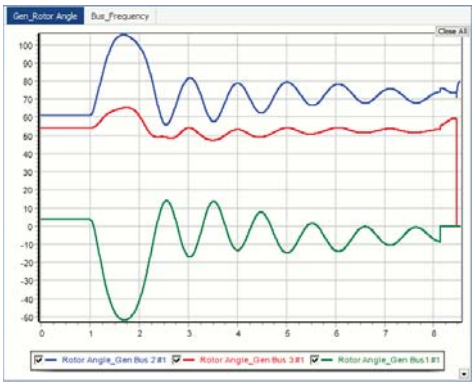


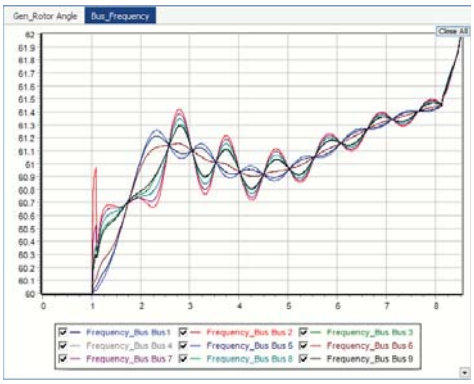
- Because this case has no governors and no infinite bus, the bus frequency keeps rising throughout the simulation, even though the rotor angles are stable.
- Go to the Generic Limit Monitors tab of the Options page. Set the generators to automatically trip as above.

WSCC_9Bus

Example: Generic Limit Monitors







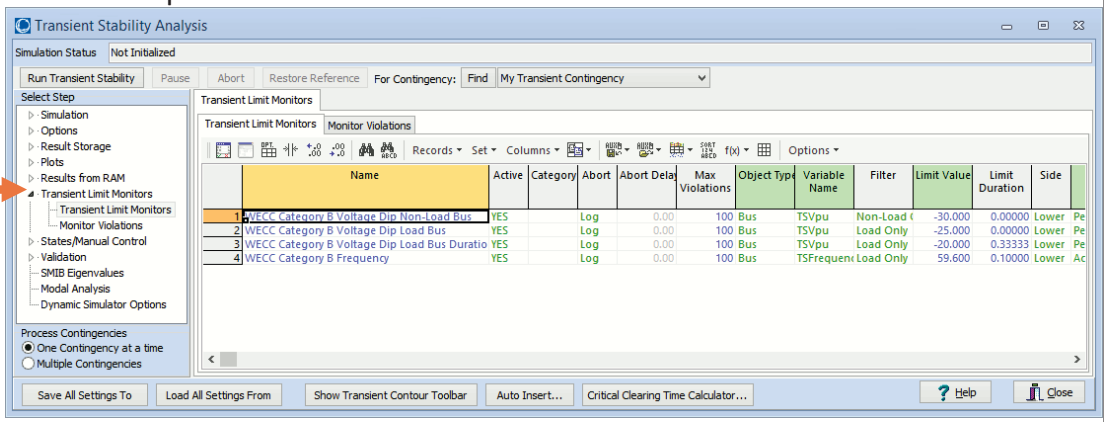
- Now, All Generators tripped out between 8 and 9 seconds (with a 0.077 seconds clearing).
- When all generators tripped out, the simulation aborts as there are no longer any viable islands.

WSCC_9Bus

Transient Limit Monitors

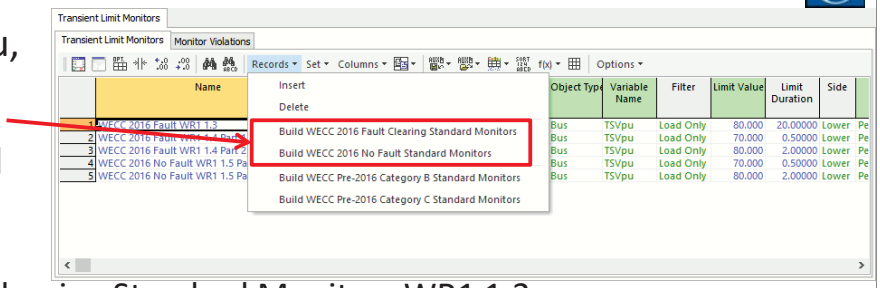
- Transient Limit Monitors in Simulator provide a great deal of flexibility for automatic monitoring during the simulation without having to store much data
- Similar to Limit Monitoring in traditional power-flow-based contingency analysis, only violations of limits will be reported
- Monitor a particular field for all objects of a type to meet a specified transient performance requirement
  - You will choose a field of a type of object
  - Then build a description of what is considered a limit violation

On the Transient Limit Monitors page of the Transient Stability Analysis dialog



Built-In Transient Limit Monitors

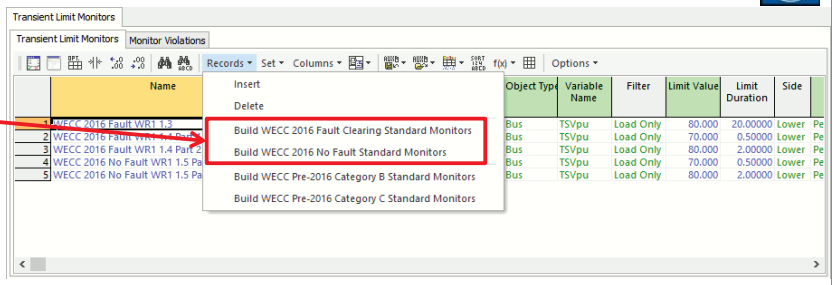
- Under **Records** menu, choices are available to **Build WECC Category B Standard Monitors** (also C)



  - WECC 2016 Fault Clearing Standard Monitors WR1 1.3
    - Monitor all load buses for voltages below to 80% of the initial value voltages for a duration of 20 seconds.
  - WECC 2016 Fault Clearing Standard Monitors WR1 1.4 Part 1
    - Monitor all load buses for voltages below to 70% of the initial value voltages for a duration of 30 cycles. Will start monitoring voltages if they are above 80% of the initial value.
  - WECC 2016 Fault Clearing Standard Monitors WR1 1.4 Part 2
    - Monitor all load buses for voltages below to 80% of the initial value voltages for a duration of 2 seconds. Will start monitoring voltages if they are above 80% of the initial value.

Built-In Transient Limit Monitors

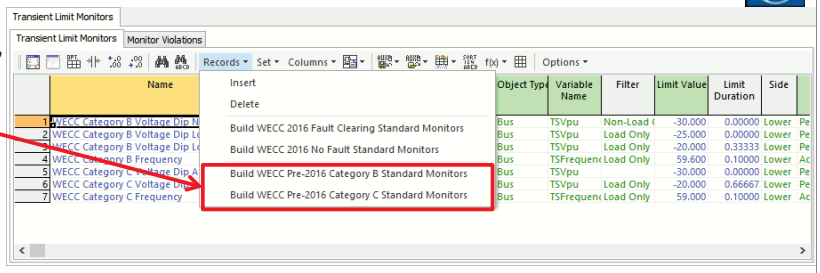
- Under **Records** menu, choices are available to **Build WECC Category B Standard Monitors** (also C)



  - WECC 2016 No Fault Standard Monitors WR1 1.5 Part 1
    - Monitor all load buses for voltages below to 70% of the initial value voltages for a duration of 30 cycles.
  - WECC 2016 No Fault Standard Monitors WR1 1.5 Part 2
    - Monitor all load buses for voltages below to 80% of the initial value voltages for a duration of 2 seconds.

Built-In Transient Limit Monitors

- Under **Records** menu, choices are available to **Build WECC Category B Standard Monitors** (also C)



  - WECC Pre-2016 Category B Voltage Dip for Non-Load Buses
    - Monitor all non-load buses for any voltage dip of 30% below the initial voltage value at any time
  - WECC Pre-2016 Category B Voltage Dip for Load Bus
    - Monitor all load buses for a voltage dip of 25% below the initial voltage at any time
  - WECC Pre-2016 Category B Voltage Dip for Load Bus Duration
    - Monitor all load buses for a voltage dip of 20% below the initial voltage for a duration of 0.3333 seconds (20 cycles)
  - WECC Pre-2016 Category B Frequency
    - Monitor all load buses for a frequency dip below 59.6 Hz for a duration of 0.10 seconds (6 cycles)

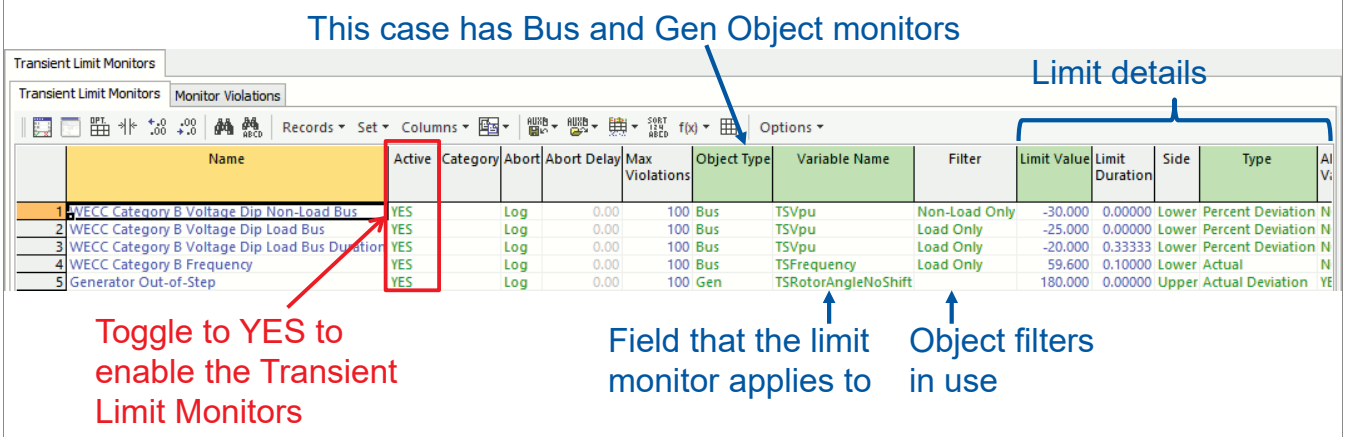
Built-In Transient Limit Monitors

- Differences as compared to Category B standards are highlighted in Red.

- WECC Pre-2016 Category C Voltage Dip for Any Bus
  - Monitor all buses for any voltage dip of 30% below the initial voltage value at any time
- WECC Pre-2016 Category C Voltage Dip for Any Bus Duration
  - Monitor all buses for a voltage dip of 20% below the initial voltage for a duration of 0.66667 seconds (40 cycles)
- WECC Pre-2016 Category C Frequency
  - Monitor all load buses for a frequency dip below 59.0 Hz for a duration of 0.10 seconds (6 cycles)

Example: Transient Limit Monitors

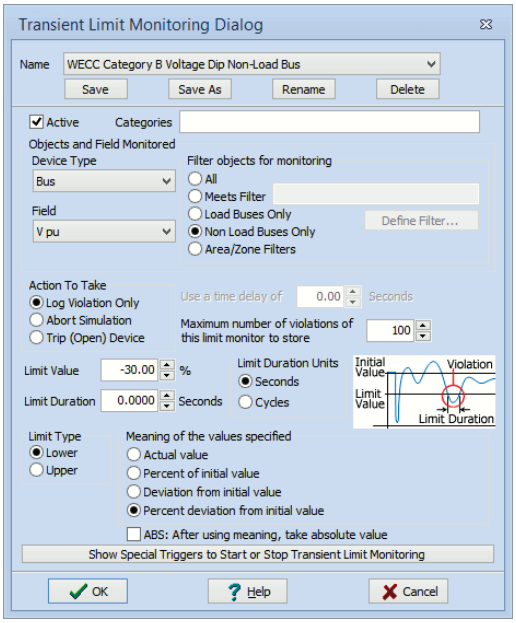
- Open "GSO_37Bus"
- Open the Transient Stability Analysis dialog to the Transient Limit Monitors page
- In the current case, there are several Transient Limit Monitors which are all initially inactive
- Toggle all items in the Active column to YES



GSO_37Bus

Transient Limit Monitors Dialog

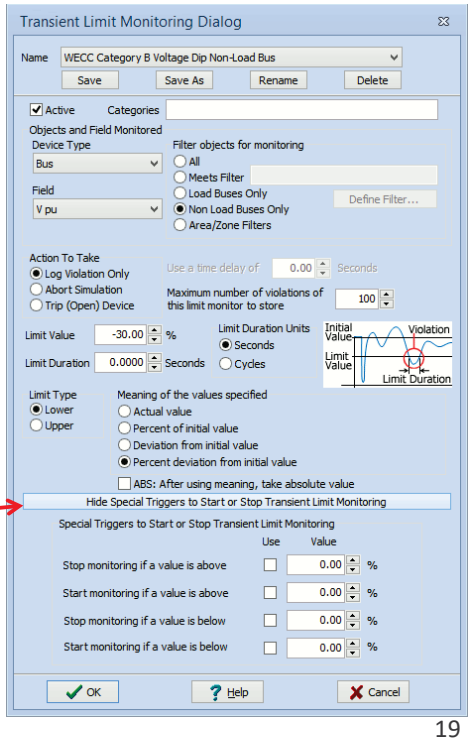
- Right click on a Transient Limit Monitor and select "Show Dialog"
- Same options are available here as on the case information display
- **Meaning of values specified** (Examples)
  - For a system with 60 Hz nominal frequency, the following are equivalent
    - *Actual value*, *Limit Value* = 59.6 Hz
    - *Deviation from initial value*, *Limit Value* = -0.4 Hz
  - When monitoring voltage, the following are equivalent
    - *Percent of initial value*, *Limit Value* = 70%
    - *Percent deviation from initial value*, *Limit Value* = -30%



GSO_37Bus

Transient Limit Monitoring Dialog

- When does transient limit monitoring start?
  - Normally transient limit monitoring does not start until AFTER the last user contingency event
  - Special options can be specified to start or stop limit monitoring as well
    - Click **Show Special Triggers to Start or Stop Transient Limit Monitoring**
    - Values specified in special triggers obey the **Meaning of values specified**



Defining Transient Limit Monitors

- When creating a new Transient Limit Monitor, give it a name and check the "Active" checkbox to make it active
- Set a particular object type and a particular field or variable name to which the limit should apply
- Set the value and type of the limit (Actual, Deviation, Percent Actual, Percent Deviation)
- Optionally, set the simulation to stop when limits are violated
- Optionally, set when monitoring of the limit should start and stop
  - "Stop below," "Start below," "Stop above," "Start above" values, plus YES/NO fields to enable each
  - This allows the monitoring of a limit to be used for customizable situations

Stop Below Use	Stop Below	Start Below Use	Start Below	Stop Above Use	Stop Above	Start Above Use	Start Above
NO	0.000	NO	0.000	NO	0.000	NO	0.000
NO	0.000	NO	0.000	NO	0.000	NO	0.000
NO	0.000	NO	0.000	NO	0.000	NO	0.000
NO	0.000	NO	0.000	NO	0.000	NO	0.000
NO	0.000	NO	0.000	NO	0.000	NO	0.000

Transient Limit Monitoring Dialog

Define what is monitored

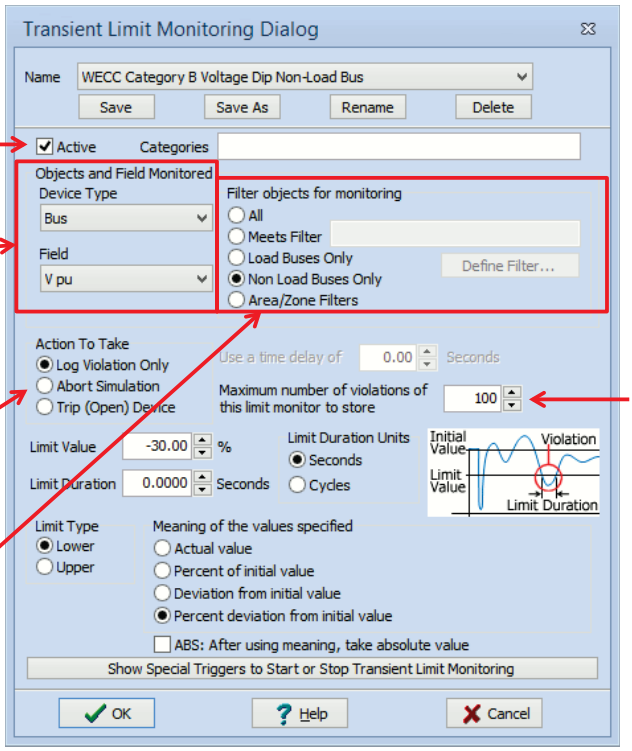
Uncheck to ignore monitoring temporarily

Choose a particular Field and Device Type

Can abort the simulation or trip device a specified time after violation

Choose Filter for which devices to monitor

Filter decision is based on the power flow solution (initial steady state)



Maximum number of violations to store

Transient Limit Monitoring Dialog

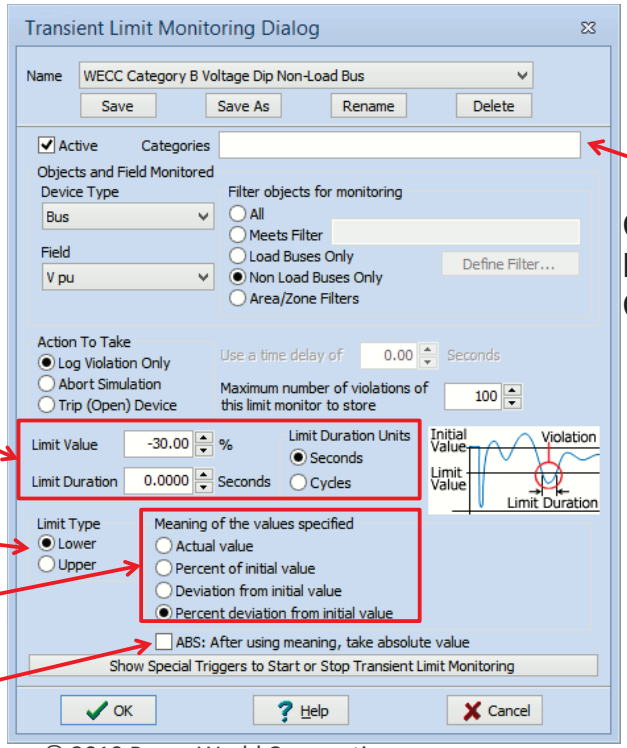
Define what is considered a limit violation

Specify Limit Value and Duration

Is this an Upper or Lower Limit?

Specify how the Limit Value and special triggers are interpreted

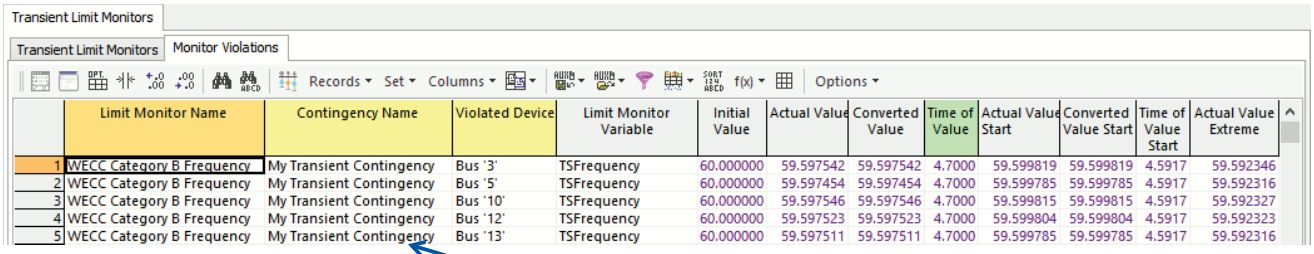
Absolute Value



Comma Delimited String Categories

Transient Limit Monitors: Monitor Violations

- As a transient stability run is processed, any violations of the Transient Limit Monitors will be shown in the Monitor Violations table
  - Shows which Limit Monitor was violated
  - Shows contingency under which violation occurs
  - Shows violated device
- If violations are found, you can revisit the run and store appropriate results
- Option to "Make a New Plot" on the Records Menu and right-click menu, will automatically generate a new Plot Definition



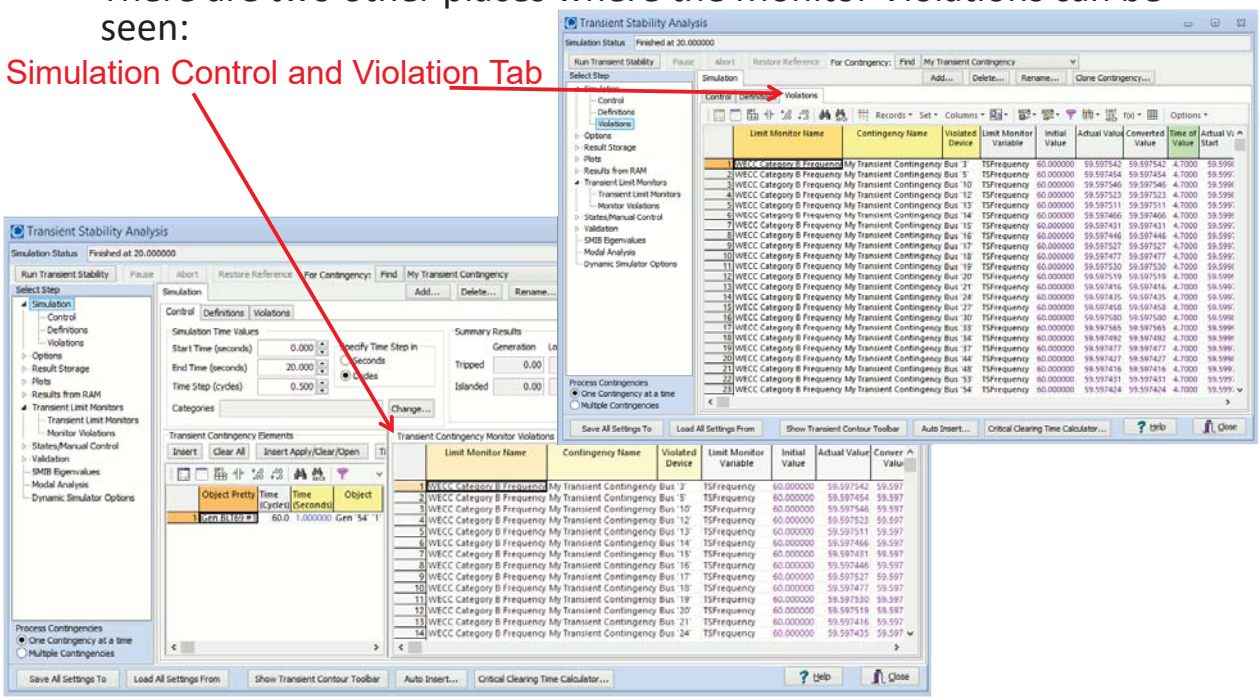
	Limit Monitor Name	Contingency Name	Violated Device	Limit Monitor Variable	Initial Value	Actual Value	Converted Value	Time of Value	Actual Value Start	Converted Value Start	Time of Value Start	Actual Value Extreme
1	WECC Category B Frequency	My Transient Contingency	Bus '3'	TSFrequency	60.000000	59.597542	59.597542	4.7000	59.599819	59.599819	4.5917	59.592346
2	WECC Category B Frequency	My Transient Contingency	Bus '5'	TSFrequency	60.000000	59.597454	59.597454	4.7000	59.599785	59.599785	4.5917	59.592316
3	WECC Category B Frequency	My Transient Contingency	Bus '10'	TSFrequency	60.000000	59.597546	59.597546	4.7000	59.599815	59.599815	4.5917	59.592327
4	WECC Category B Frequency	My Transient Contingency	Bus '12'	TSFrequency	60.000000	59.597523	59.597523	4.7000	59.599804	59.599804	4.5917	59.592323
5	WECC Category B Frequency	My Transient Contingency	Bus '13'	TSFrequency	60.000000	59.597511	59.597511	4.7000	59.599785	59.599785	4.5917	59.592316

When running multiple contingencies, you can see which one caused the violation

Transient Limit Monitors: Monitor Violations

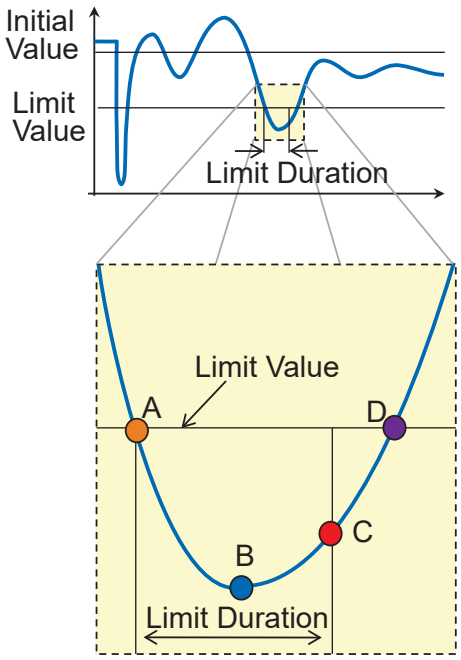
- There are two other places where the Monitor Violations can be seen:

Simulation Control and Violation Tab



Transient Limit Monitors: Monitor Violations

- Values reported by Monitor Violations
  - Violation (Point C)
    - Value
    - Time of Value
  - Extreme (Point B)
    - Extreme Value
    - Time of Extreme Value
    - Note: could be after point C also
  - Start of Violation (Point A)
    - Value Start
    - Time of Value Start
  - Value no longer violating (Point D)
    - Value No Violation
    - Time of Value No Violation
    - Note: Point may not exist

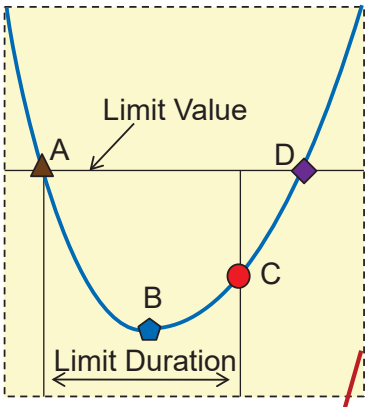


Monitor Violations: Example

- Run the simulation
- Open the Transient Limit Monitors page and view the violations
- The "Generator Out-of-Step" limit monitor has several violations

Monitor Violations Tab- View the violations

For this example, points A and C are the same because the Limit Duration is 0



Transient Limit Monitors

Transient Limit Monitors | Monitor Violations

Records | Set | Columns | Options

	Limit Monitor Name	Contingency Name	Violated Device	Limit Monitor Variable	Initial Value	Actual Value	Time of Value	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	My Transient Contingency	Bus '3'	TSFrequency	60.000000	59.597542	4.7000	59.599819	4.5917	59.592346	5.4500	59.600174	6.3667
2	WECC Category B Frequency	My Transient Contingency	Bus '5'	TSFrequency	60.000000	59.597454	4.7000	59.599785	4.5917	59.592316	5.4500	59.600231	6.3667
3	WECC Category B Frequency	My Transient Contingency	Bus '10'	TSFrequency	60.000000	59.597546	4.7000	59.599815	4.5917	59.592327	5.4500	59.600128	6.3667
4	WECC Category B Frequency	My Transient Contingency	Bus '12'	TSFrequency	60.000000	59.597523	4.7000	59.599804	4.5917	59.592323	5.4500	59.600159	6.3667
5	WECC Category B Frequency	My Transient Contingency	Bus '13'	TSFrequency	60.000000	59.597511	4.7000	59.599785	4.5917	59.592316	5.4500	59.600155	6.3667
6	WECC Category B Frequency	My Transient Contingency	Bus '14'	TSFrequency	60.000000	59.597466	4.7000	59.599907	4.5917	59.592388	5.4500	59.600105	6.3500
7	WECC Category B Frequency	My Transient Contingency	Bus '15'	TSFrequency	60.000000	59.597431	4.7000	59.599770	4.5917	59.592281	5.4500	59.600182	6.3667
8	WECC Category B Frequency	My Transient Contingency	Bus '16'	TSFrequency	60.000000	59.597446	4.7000	59.599773	4.5917	59.592289	5.4500	59.600182	6.3667

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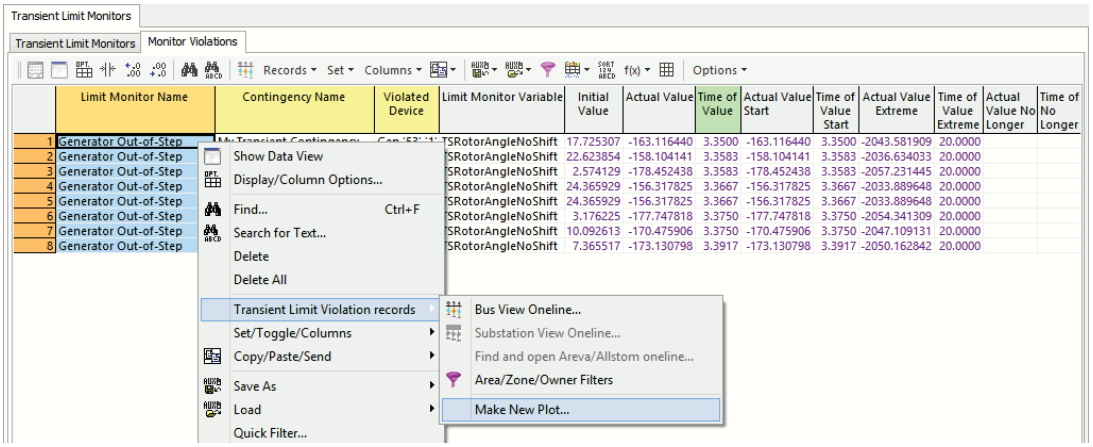
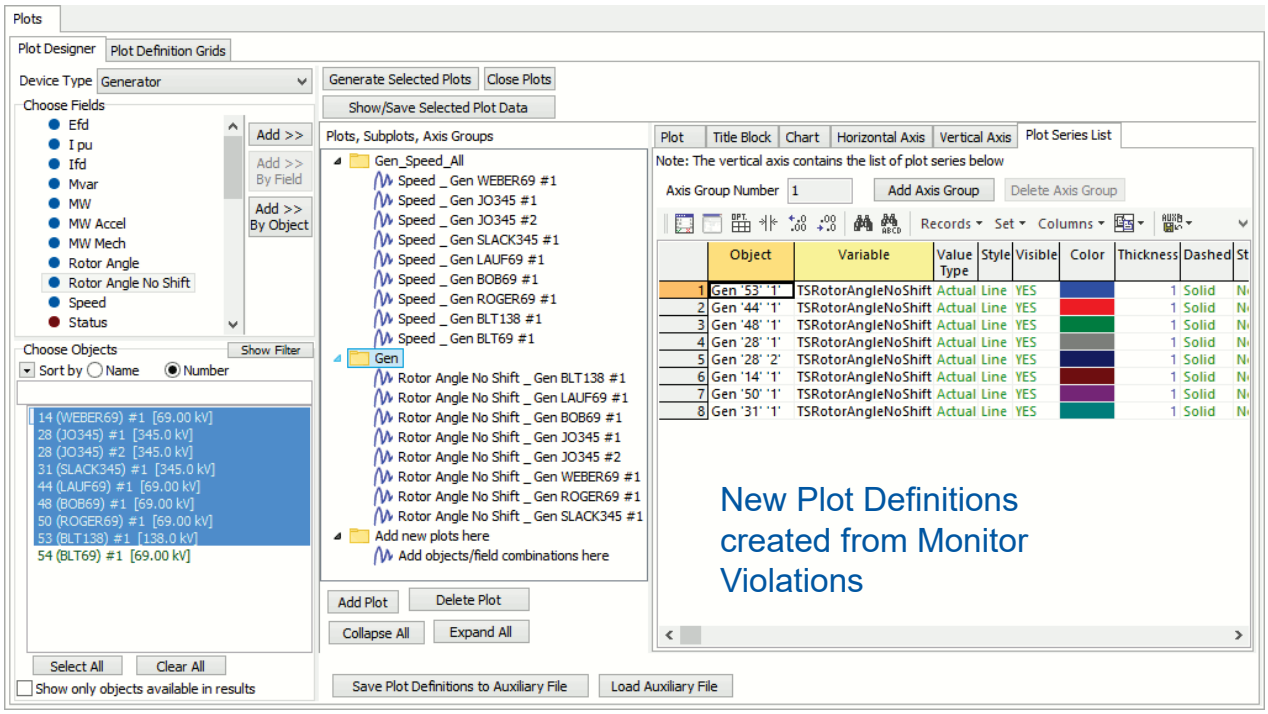
Monitor Violations: Example

- You can add Plot Definitions for variables which are violating the limit monitors
- Select all the violations, right click, choose “Make New Plot”

Create Plot Definitions for violating fields



Monitor Violations: Example



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