

Transient Stability Analysis with PowerWorld Simulator



T5: Transient Contingencies



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Transient Stability Analysis: PowerWorld's Design Goal



- Traditional transient stability
 - Create one set of events which define your transient stability simulation
 - Similar to having a tool to solve one power flow solution
- PowerWorld's Design Goal
 - Mimic the processing of Simulator's Contingency Analysis
 - Define multiple contingencies and process them all
 - This section will concentrate on defining a single transient contingency
- This leads to creating a new object in Simulator called a *Transient Contingency*
 - Similar to Contingency records except a different set of actions are available
 - Also timing inputs are important

Transient Contingencies



- Goal - to simulate a particular contingency and see if it causes any problems for the system
- A transient contingency will consist of one or more events
- One contingency might be the outage of a generator to gauge the response of the governors of the remaining generators
- Another contingency might simulate a bus fault, which has events to both initiate and clear the fault

Defining a Transient Contingency



- A new contingency will automatically be given an unused name starting with “My Transient Contingency”
- Several buttons are normally available at the top of the dialog regardless of the page which are used for processing transient contingencies
- More than one contingency may be specified



- Use Add, Delete, and Rename buttons to manage the transient contingencies
- Use the drop-down menu to choose the presently active contingency from a list of available contingencies

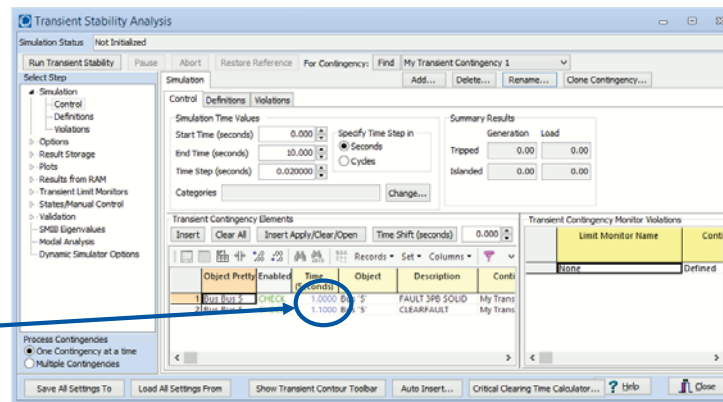
Transient Contingency



- Specify Start and End Time
- Specify Time Step (seconds or cycles)
 - Recommend either 0.5 cycles or 0.25 cycles
- Transient Contingencies have one or more Transient Contingency Elements to specify the events that occur during the simulation
 - Fault Bus
 - Open Line
 - Etc...

A Transient Contingency with two Transient Contingency Elements

Contingency elements are associated with time



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Transient Contingency Elements



- Insert Elements Button
 - Opens the Transient Stability Contingency Element Dialog
- Clear All Elements
 - Deletes all currently defined events
- Insert Apply and Clear Fault
 - Quickly apply/clear a fault by specifying both its fault time and its clearing time in one dialog
- Element Table
 - A case information display which lists all transient stability elements currently defined for the Transient Contingency
 - Clicking on an event and choosing “Show Dialog” option will open the Transient Stability Contingency Element Dialog

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Transient Contingency Element Actions Types



- Bus
 - Apply Fault
 - Apply the specified fault type (Balanced 3 phase, Single Line to Ground, Line to Line, or Double Line to Ground)
 - Fault Across – (Solid, with Impedance and specifying PU Resistance and PU Reactance, or with Admittance specifying PU Conductance and PU Susceptance)
 - Clear Fault
- Generator
 - Open the generator.
 - Close the generator.
 - Ramp Values : Output , Exciter Setpoint (Vref), Governor Setpoint (Pref) Set Values
 - Set Value: Output , Exciter Setpoint (Vref), Governor Setpoint (Pref)
- Load
 - Open
 - Close
 - Set Values

Transient Contingency Element Actions Types



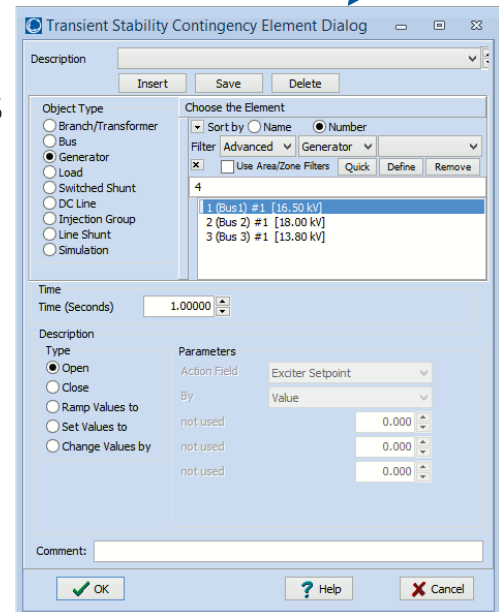
- Switched Shunt
 - Open
 - Close
- AC Line/Transformer
 - Apply Fault
 - Apply the specified fault type (Balanced 3 phase, Single Line to Ground, Line to Line, or Double Line to Ground)
 - Fault Across – (Solid, with Impedance and specifying PU Resistance and PU Reactance, or with Admittance specifying PU Conductance and PU Susceptance)
 - Percent Location
 - Clear Fault
 - Open : Both Ends, From End Only, To End Only, One Phase Open
 - Close : Both Ends, From End Only, To End Only
 - Bypass, and Not Bypass: intended for series capacitors
- DC Line
 - Open

Creating Transient Contingency Elements



- Click **Insert Elements**, or Choose **Records, Insert**
- Transient Contingency Elements involve specifying the following:
 - Object element is applied to
 - Time element occurs
 - Event Type
 - Parameters for element

Transient Contingency Element Dialog



TS9Bus Example



- Open **TS9BusNoModels.pwb**
- With PowerWorld Simulator, a power flow case can be quickly transformed into a transient stability case
 - This requires the addition of at least one dynamic model
- We will now go through how to transform a power flow case into a transient stability case
- Add a dynamic generator model to an existing “no model” power flow case by:
 - In run mode, right-click on the generator symbol for bus 1, then select “Generator Information Dialog” from the local menu
 - This displays the Generator Information Dialog, select the “Stability” tab to view the transient stability models; none are initially defined.

Inserting a Model



- From the Generator Information Dialog, insert a GENSAL model (represents a salient pole machine)

Click to insert a machine model

Choose GENSAL

Click "OK"

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Inserting a Model



- GENSAL Dialog for Bus 1 now looks like this-

GENSAL is the only machine model inserted for this generator, so it was automatically made active

If you add more models, you need to select which to make active

| | | | |
|------|---------|-------|---------|
| H | 3.00000 | Tdop | 7.00000 |
| D | 0.00000 | Tdopp | 0.04000 |
| Ra | 0.00000 | Taopp | 0.05000 |
| Xd | 2.10000 | S1 | 0.00000 |
| Xq | 0.50000 | S12 | 0.00000 |
| Xdp | 0.20000 | RComp | 0.00000 |
| Xdpp | 0.18000 | XComp | 0.00000 |
| Xl | 0.15000 | | |

Default parameters are present

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Inserting a Model



- Modify the machine parameters at Bus 1 to match those shown here

Generator Information for Present

Bus Number: 1, Bus Name: Bus 1, ID: 1, Area Name: 1 (1), Labels: no labels, Generator MVA Base: 100.00, Fuel Type: Unknown, Unit Type: UN (Unknown)

Status: Open, Closed

Energized: NO (Offline), YES (Online)

Machine Models: Exciters, Governors, Stabilizers, Other Models, Step-up Transformer, Terminal and State

Type: Active - GENSAL, Active (only one may be active)

Parameters (PU values shown/entered using device base of 100.0 MVA):

| | | | |
|------|----------|-------|---------|
| H | 23.64000 | Tdop | 8.96000 |
| D | 4.72800 | Tdopp | 0.31000 |
| Ra | 0.00000 | Tqopp | 0.31000 |
| Xd | 0.14600 | S1 | 0.00000 |
| Xq | 0.09690 | S12 | 0.00000 |
| Xdp | 0.06080 | RComp | 0.00000 |
| Xdpp | 0.06080 | XComp | 0.00000 |
| Xi | 0.03040 | | |

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Inserting a Model



- Repeat for Generators 2 and 3

Generator Information for Present

Bus Number: 2, Bus Name: Bus 2, ID: 1, Area Name: 1 (1), Labels: no labels, Generator MVA Base: 100.00, Fuel Type: Unknown, Unit Type: UN (Unknown)

Status: Open, Closed

Energized: NO (Offline), YES (Online)

Machine Models: Exciters, Governors, Stabilizers, Other Models, Step-up Transformer, Terminal and State

Type: Active - GENSAL, Active (only one may be active)

Parameters (PU values shown/entered using device base of 100.0 MVA):

| | | | |
|------|---------|-------|---------|
| H | 6.40000 | Tdop | 6.00000 |
| D | 1.28000 | Tdopp | 0.53500 |
| Ra | 0.00000 | Tqopp | 0.53500 |
| Xd | 0.89580 | S1 | 0.00000 |
| Xq | 0.86450 | S12 | 0.00000 |
| Xdp | 0.11980 | RComp | 0.00000 |
| Xdpp | 0.11980 | XComp | 0.00000 |
| Xi | 0.05990 | | |

Generator Information for Present

Bus Number: 3, Bus Name: Bus 3, ID: 1, Area Name: 1 (1), Labels: no labels, Generator MVA Base: 100.00, Fuel Type: Unknown, Unit Type: UN (Unknown)

Status: Open, Closed

Energized: NO (Offline), YES (Online)

Machine Models: Exciters, Governors, Stabilizers, Other Models, Step-up Transformer, Terminal and State

Type: Active - GENSAL, Active (only one may be active)

Parameters (PU values shown/entered using device base of 100.0 MVA):

| | | | |
|------|---------|-------|---------|
| H | 3.01000 | Tdop | 5.89000 |
| D | 0.60200 | Tdopp | 0.60000 |
| Ra | 0.00000 | Tqopp | 0.60000 |
| Xd | 1.31250 | S1 | 0.00000 |
| Xq | 1.25780 | S12 | 0.00000 |
| Xdp | 0.18130 | RComp | 0.00000 |
| Xdpp | 0.18130 | XComp | 0.00000 |
| Xi | 0.09060 | | |

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Model Explorer – Machine Models

The screenshot shows the 'Model Explorer: Generator Machine Models' window. The 'Machine Model' list on the left includes GENPWF, GENPWS, GENPWTWO, GENROE, GENROU, GENSAE, GENSAE (3), GENTPF, GENTPJ, GENTPW, and GENTPW (3). The main table displays parameters for three buses:

| Number of Bus | ID | Name_Nominal kV of Bus | Name of Bus | Type | MVA Base | Device Status | Sub-Intervals | H | D | Ra | Xd | Xq | Xdp | Xdpp |
|---------------|----|------------------------|-------------|--------|----------|---------------|---------------|-------|-------|----|--------|--------|--------|--------|
| 1 | 1 | Bus1_16.50 | Bus1 | GENSAL | 100 | Active | | 23.64 | 4.728 | 0 | 0.146 | 0.0969 | 0.0608 | 0.0608 |
| 2 | 2 | Bus2_18.00 | Bus2 | GENSAL | 100 | Active | | 6.4 | 1.28 | 0 | 0.8958 | 0.8645 | 0.1198 | 0.1198 |
| 3 | 3 | Bus3_13.80 | Bus3 | GENSAL | 100 | Active | | 3.01 | 0.602 | 0 | 1.3125 | 1.2578 | 0.1813 | 0.1813 |

Below the table, a callout box highlights the following parameters:

| H | D | Ra | Xd | Xq | Xdp | Xdpp | XI | Tdop | Tdopp | Tqopp | S1 | S12 | RComp | XComp |
|-------|-------|----|--------|--------|--------|--------|--------|------|-------|-------|----|-----|-------|-------|
| 23.64 | 4.728 | 0 | 0.146 | 0.0969 | 0.0608 | 0.0608 | 0.0304 | 8.96 | 0.31 | 0.31 | 0 | 0 | 0 | 0 |
| 6.4 | 1.28 | 0 | 0.8958 | 0.8645 | 0.1198 | 0.1198 | 0.0599 | 6 | 0.535 | 0.535 | 0 | 0 | 0 | 0 |
| 3.01 | 0.602 | 0 | 1.3125 | 1.2578 | 0.1813 | 0.1813 | 0.0906 | 5.89 | 0.6 | 0.6 | 0 | 0 | 0 | 0 |

Can verify or change parameters here

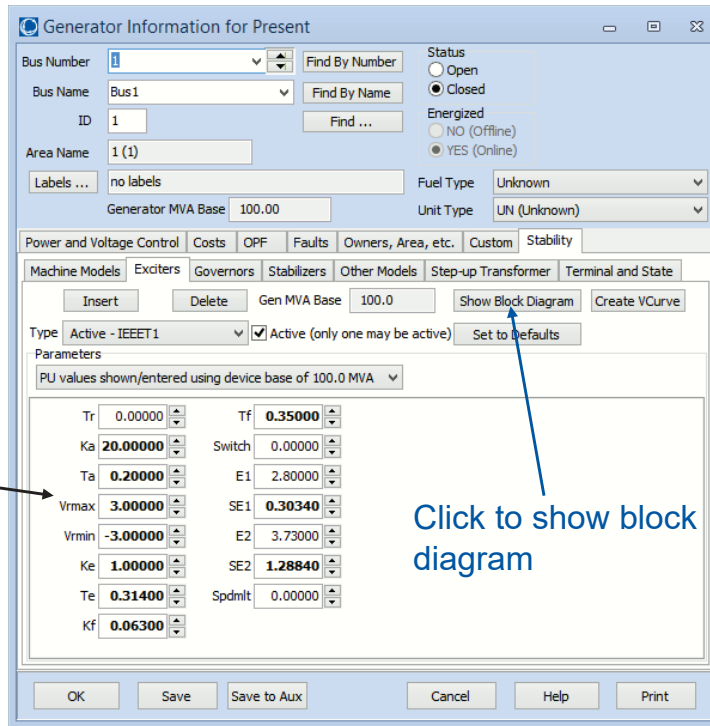
Adding a Generator Exciter

- The purpose of the generator excitation system (exciter) is to adjust the generator field current to maintain a constant terminal voltage.
- PowerWorld Simulator includes many different types of exciter models. One simple exciter is the IEEE1. To add this exciter to the generator dialog, “Stability” tab, “Exciters” page. Click Insert and then select IEEE1 from the list.
- The IEEE1 is by far the most common exciter used in the 2006 MMWG case; the next most common is its close relative, the IEEEEX1.

Insert Exciter Models

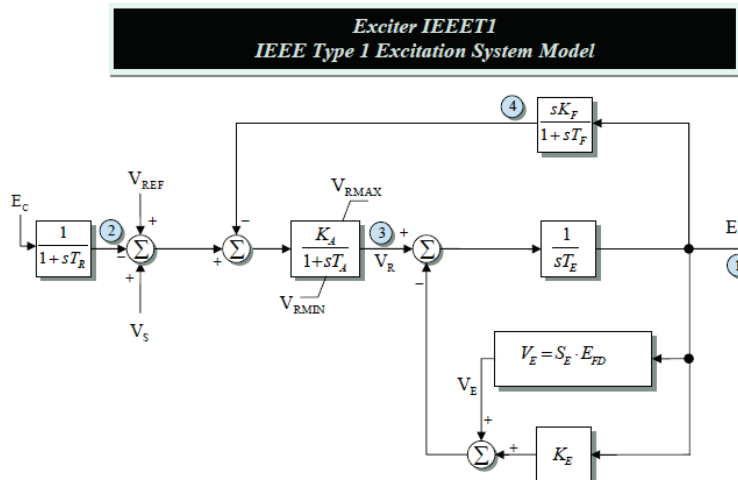
Add IEEE11 Exciter models to all three generators

Change settings for all three exciters to match these



IEEE11 Exciter

- You can view the block diagram for the IEEE11 exciter by clicking on the "Show Diagram" button.
- This opens a PDF file in Adobe Reader to the page with the appropriate block diagram (shown below).



The input to the exciter, E_C , is usually the terminal voltage. The output, E_{FD} , is the machine field voltage.

Model Explorer - Exciters

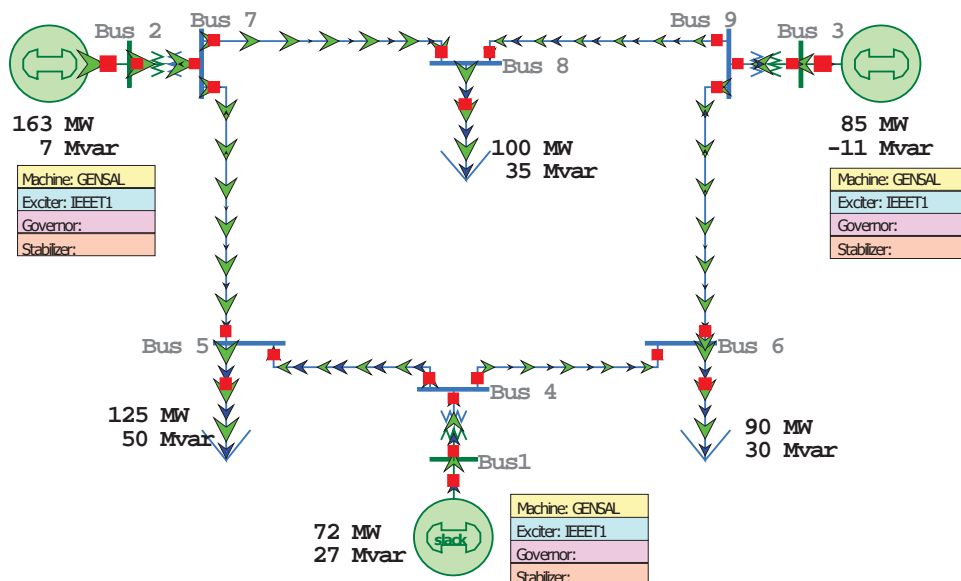
Model Explorer: Generator Exciters

Filter: Advanced | Exciter: IEEET1

| Number of Bus | ID | Name_Nominal kV of Bus | Name of Bus | Type | MVA Base | Device Status | SUB-Interval | Tr | Ka | Ta | Vrmax | Vrmin | Ke | Te | Kf | Tf | Switch | E1 | SE1 | E2 | SE2 | Spdmlt | |
|---------------|-----|------------------------|-------------|--------|----------|---------------|--------------|----|----|-----|-------|-------|----|-------|-------|------|--------|----|-----|--------|------|--------|---|
| 1 | 1 1 | Bus1_16.50 | Bus1 | IEEET1 | 100 | Active | | 0 | 20 | 0.2 | 3 | -3 | 1 | 0.314 | 0.063 | 0.35 | | 0 | 2.8 | 0.3034 | 3.73 | 1.2884 | 0 |
| 2 | 2 1 | Bus 2_18.00 | Bus 2 | IEEET1 | 100 | Active | | 0 | 20 | 0.2 | 3 | -3 | 1 | 0.314 | 0.063 | 0.35 | | 0 | 2.8 | 0.3034 | 3.73 | 1.2884 | 0 |
| 3 | 3 1 | Bus 3_13.80 | Bus 3 | IEEET1 | 100 | Active | | 0 | 20 | 0.2 | 3 | -3 | 1 | 0.314 | 0.063 | 0.35 | | 0 | 2.8 | 0.3034 | 3.73 | 1.2884 | 0 |

Can verify or change parameters here

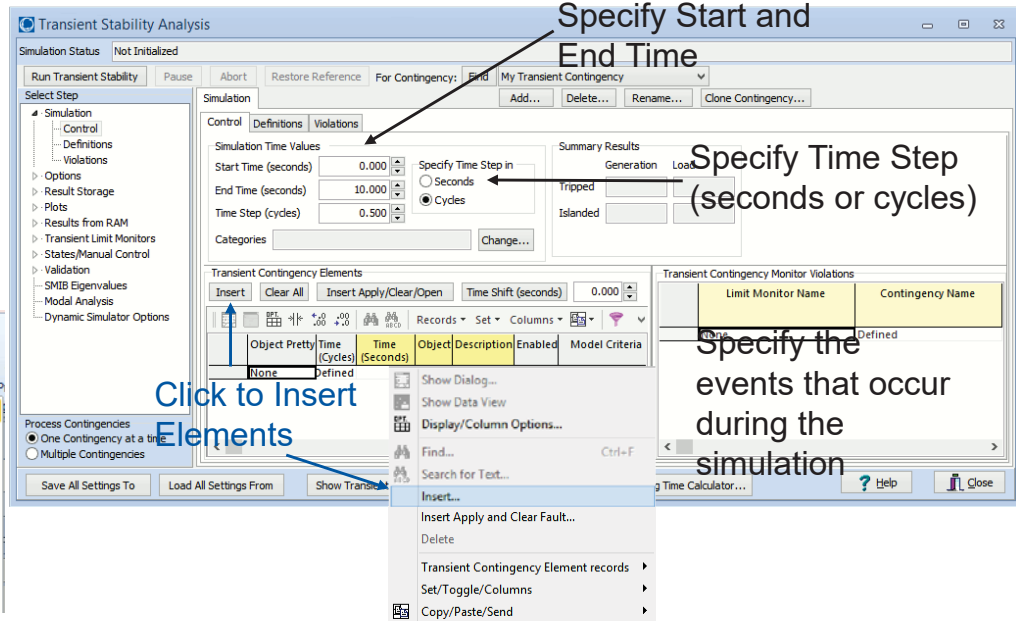
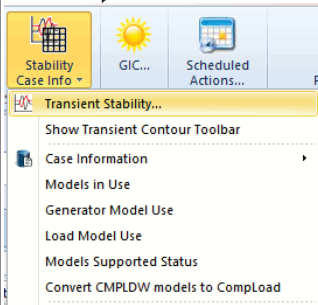
TS9Bus System with Machine and Exciter Models



Define a Transient Contingency



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



Transient Stability Contingency Element Dialog



- Clicking “Insert” opens the Transient Stability Contingency Element Dialog shown below
- This dialog is used to specify transient stability events and when they occur

Object Type

- Changes the type of events that can occur

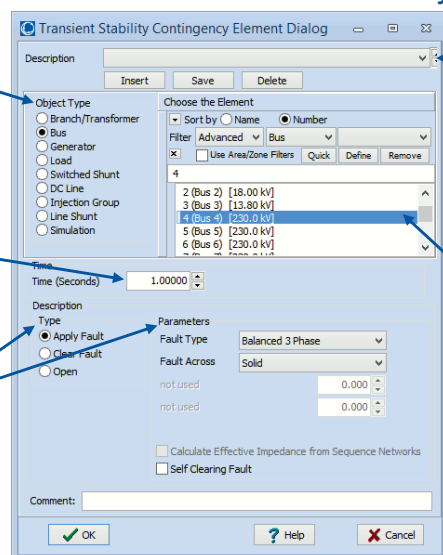
Time

- When the event occurs

Event Type and Parameters

- Depends on Object Type

No events have been defined yet



Description

- A drop-down list of all currently defined events
- May be used to switch between events and modify them as necessary
- Appears once the event is saved

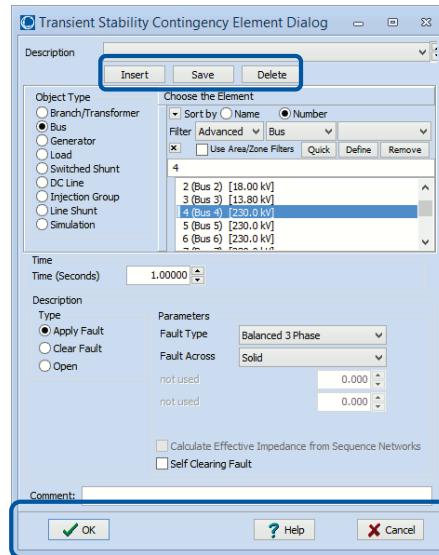
Choose the Element

- Apply the event to this element
- List is updated as Object Type is changed

Transient Stability Contingency Element Dialog



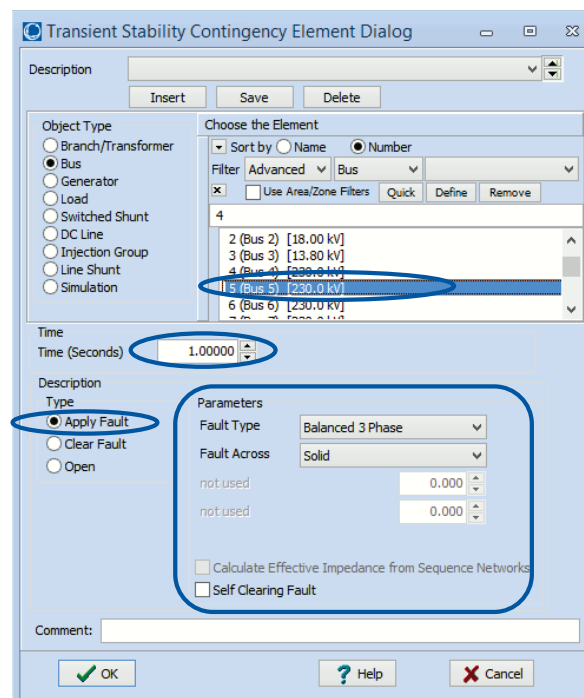
- “Save” will save any modifications but leave the dialog open
- “Insert” creates a new event with the specified parameters
- “OK” will accept changes and close the dialog
- “Delete” will delete the event defined by the event Description
- “Cancel” closes the dialog without saving



Add a Fault at Bus 5



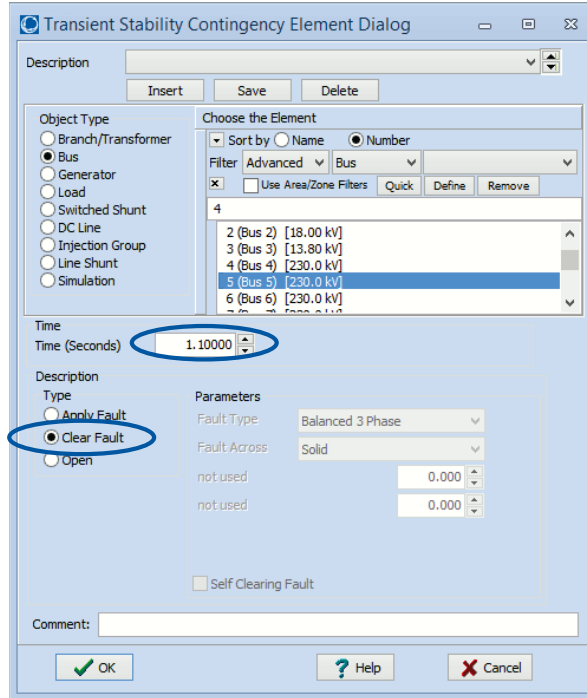
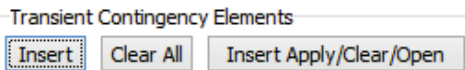
- Apply a balanced solid three-phase fault on Bus 5 at time = 1.00 seconds



Clear Fault at Bus 5

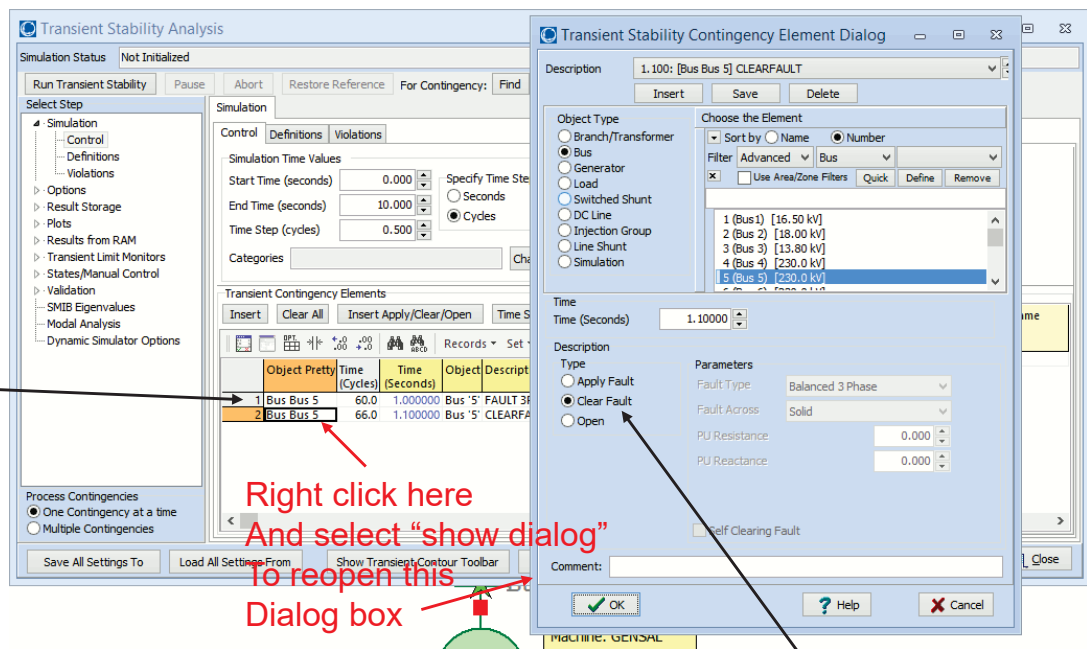
- Clear the Bus 5 fault at time = 1.10 seconds

Note: could have also used the **Insert Apply/Clear/Open** button



Transient Contingency Definition

Summary of all elements in contingency and time of action

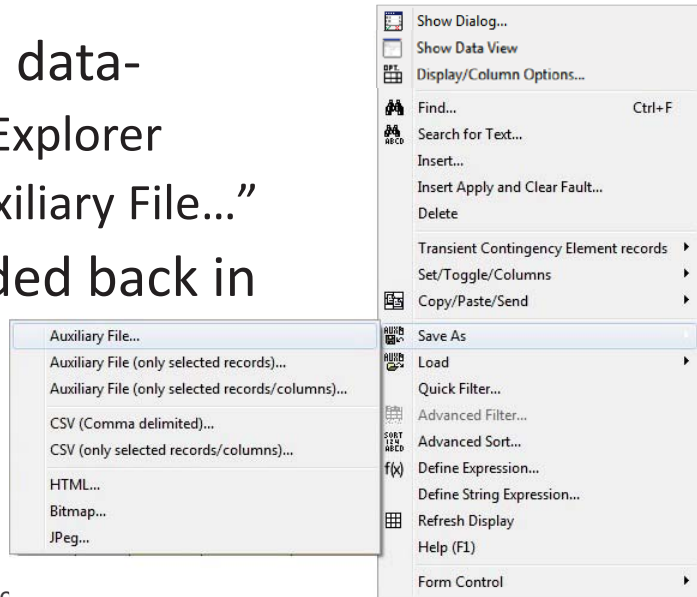


Available element type will vary with different objects

AUX files to Save/Load Model Data



- Any of the model data can be saved into AUX files
- Save machine model data-
 - Right click in Model Explorer
 - Select “Save As” “Auxiliary File...”
- This data can be loaded back in

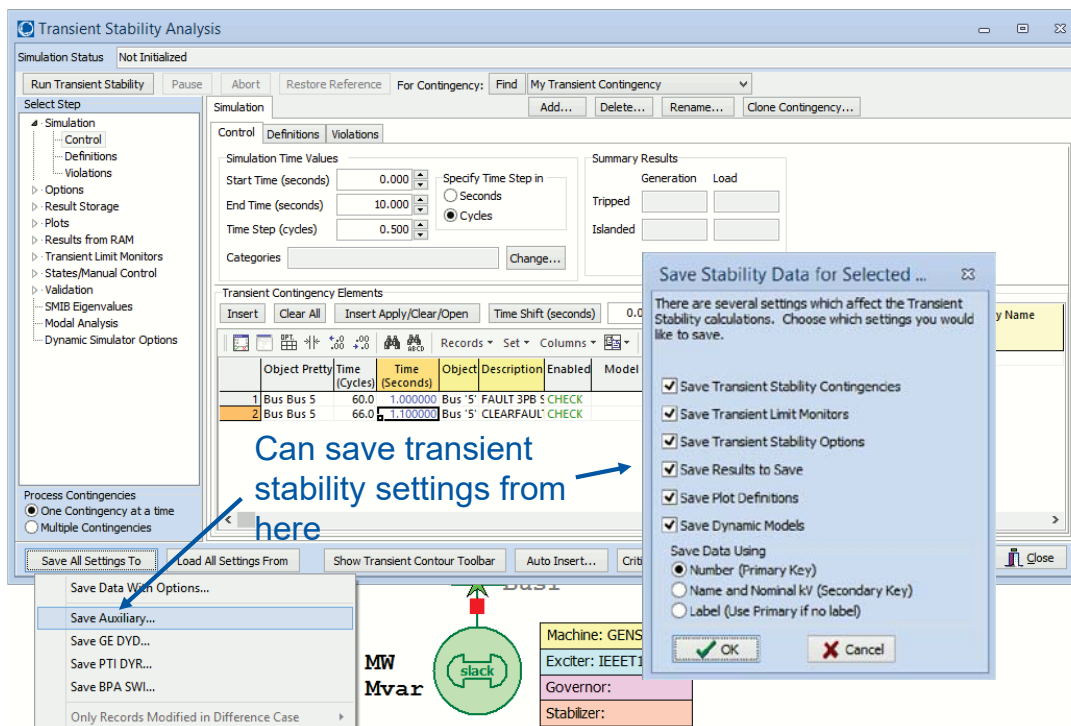


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Save Stability Settings



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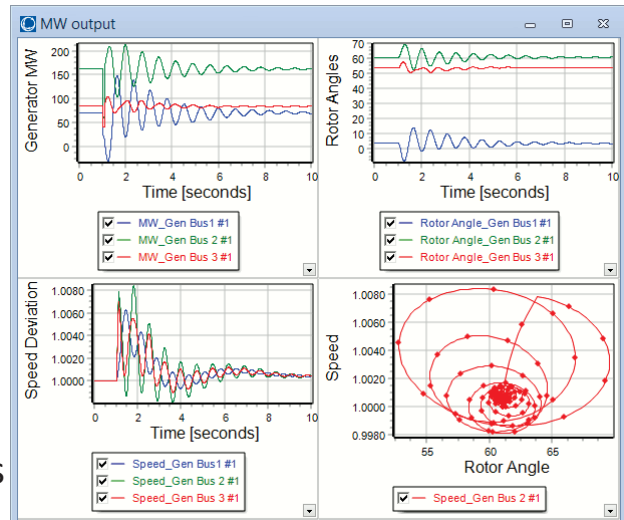
TS9BusNoModels.pwb

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Load in Plot Settings



- The machine models and exciter models for this example can also be loaded in from **TS9ExciterModels.aux** and **TS9MachModels.aux**
- Save the case with the models and events as **TS9Bus Bus Fault NoPlot**
- Go to Stability Case Info, Load Transient Stability Data, Load Auxiliary
- Load in the AUX file **TS9Bus Bus FaultPLOTDEFN.aux** which contains some plot settings that we will talk about in detail in a later section
- Save the case as **TS9BusCtgEx**
- Click “Run Transient Stability” to simulate the models and the events that you inserted



Example: Changing Contingency Elements



- Suppose you want to change the events that are simulated for a particular contingency
- We will change the elements of this Transient Contingency from a bus fault at Bus 5 to a fault between Bus 4 and Bus 5 near bus 5
- There are several ways this can be done
 - On the Simulation page, clicking “Clear All Elements” will remove the existing elements; you can then add new ones
 - You can right-click on an existing element and open the Transient Contingency Element Dialog and change the events directly

Example: Changing Contingency Elements



Simulation

Control Definitions Violations

Simulation Time Values

Start Time (seconds) 0.000 Specify Time Step in

End Time (seconds) 10.000 Seconds

Time Step (cycles) 0.500 Cycles

Categories Change...

Summary Results

Generation Load

Tripped 0.00

Islanded 0.00

Transient Contingency Elements

Insert Clear All Insert Apply/Clear/Open Time Shift (seconds) 0.000

| Object | Pretty | Time | Time | Object | Description | Enabled | Model |
|--------|-----------|----------|-----------|---------|-------------|---------|----------|
| | | (Cycles) | (Seconds) | | | | Criteria |
| 1 | Bus Bus 5 | 60.0 | 1.000000 | Bus '5' | FAULT 3PB S | CHECK | |
| 2 | Bus Bus 5 | 66.0 | 1.100000 | Bus '5' | CLEARFAULT | CHECK | |

Transient Stability Contingency Element Dialog

Description

Insert Save Delete

Object Type

Choose the Element

Sort by Name Number

Filter Advanced Bus

Use Area/Zone Filters Quick Define Remove

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2 (Bus 2) [18.00 kV]

3 (Bus 3) [13.80 kV]

4 (Bus 4) [230.0 kV]

5 (Bus 5) [230.0 kV]

6 (Bus 6) [230.0 kV]

Time

Time (Seconds) 1.00000

Description

Type

Apply Fault

Clear Fault

Open

Parameters

Fault Type Balanced 3 Phase

Fault Across Solid

Percent Location (near to far) 0.000

Calculate Effective Impedance from Sequence Networks

Self Clearing Fault

Comment:

OK Help Cancel

- Right-click on the first Transient Contingency Element and open the Transient Stability Contingency Element dialog
- First, change “Object Type,” from Bus to Branch/Transformer to view choices for that object type

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Example: Changing Contingency Elements



- “Choose the Element”
 - Make sure the Near Bus is selected to be 5 and Far Bus is selected to be 4
- “Time”
 - Time (Seconds) – set to 1.00
- “Description”
 - “Apply Fault” should be selected
- “Parameters”
 - Fault Type – set to Balanced 3 Phase
 - Fault Across – set to Solid
 - Percent Location (near to far) – set to 0.00

Transient Stability Contingency Element Dialog

Description 1.000: [Bus 5] FAULT 3PB SOLID

Insert Save Delete

Object Type

Choose the Element

Sort by Name Number

Filter Advanced Branch

Use Area/Zone Filters Quick Define Remove

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Search For Near Bus Select Far Bus, OK

3 (Bus 3) [13.80 kV]

4 (Bus 4) [230.0 kV] CKT 1

5 (Bus 5) [230.0 kV]

6 (Bus 6) [230.0 kV]

Time

Time (Seconds) 1.00000

Description

Type

Apply Fault

Clear Fault

Open

Close

Bypass

Not Bypass

Set Values

Parameters

Fault Type Balanced 3 Phase

Fault Across Solid

Percent Location (near to far) 0.000

Calculate Effective Impedance from Sequence Networks

Self Clearing Fault

Comment:

OK Help Cancel

T5: Transient Contingency

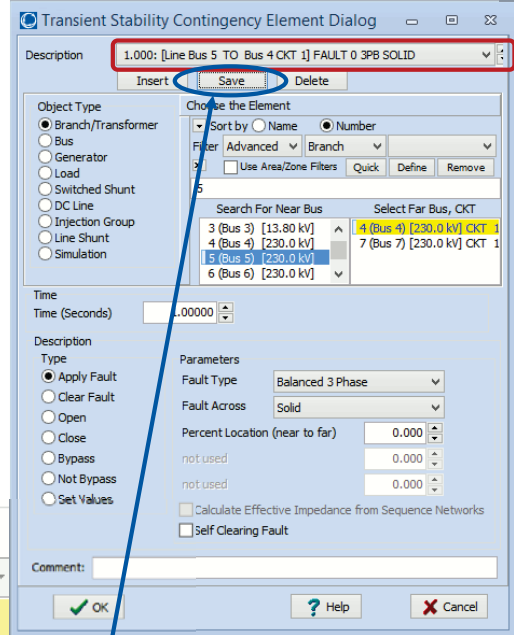
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Example: Changing Contingency Elements

- After verifying these changes, click “Save”
- Once you click save, the Description at the top changes to reflect that this is now a branch fault
- Then, click OK to close the dialog
- Now the first Transient Contingency Element in the case information display has changed

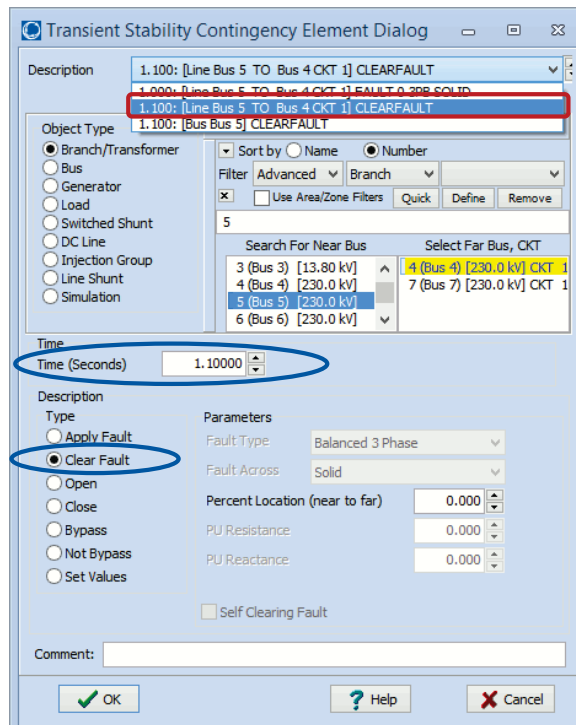


| Object Pretty | Time (Cycles) | Time (Seconds) | Object | Description | |
|-----------------------------|---------------|----------------|--------------------|-------------------|--------------------------|
| 1 Line Bus 5 TO Bus 4 CKT 1 | 60.0 | 1.0000000 | Branch '5' '4' '1' | FAULT 0 3PB SOLID | My Transient Contingency |
| 2 Bus Bus 5 | 66.0 | 1.1000000 | Bus '5' | CLEARFAULT | My Transient Contingency |

After clicking “Save,” the Description and Case Information Displays will update

Example: Changing Contingency Elements

- Right-click on the second Transient Contingency Element and open the Transient Stability Contingency Element dialog
- From the Description drop-down menu, select the description for the element that you just created
- Change the time to 1.1
- Change Apply Fault to Clear Fault
- All other parameters are unchanged
- Click Insert – a new contingency element with a new name has been created



Example: Changing Contingency Elements



Transient Contingency Elements

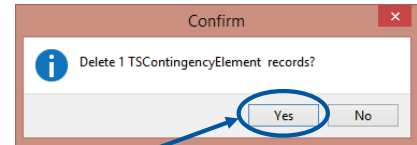
| Object Pretty | Time (Cycles) | Time (Seconds) | Object | Description | Contingency Name |
|-----------------------------|---------------|----------------|--------------------|-------------------|--------------------------|
| 1 Line Bus 5 TO Bus 4 CKT 1 | 60.0 | 1.000000 | Branch '5' '4' '1' | FAULT 0 3PB SOLID | My Transient Contingency |
| 2 Line Bus 5 TO Bus 4 CKT 1 | 66.0 | 1.100000 | Branch '5' '4' '1' | CLEARFAULT | My Transient Contingency |
| 3 Bus Bus 5 | | | | CLEARFAULT | My Transient Contingency |

Right-click and choose "Delete"

Confirm the decision to delete the record

Table showing the new Transient Contingency Elements

- Click OK to close the dialog
- We still need to delete the third Transient Contingency Element which had been used previously for clearing the Bus 5 fault



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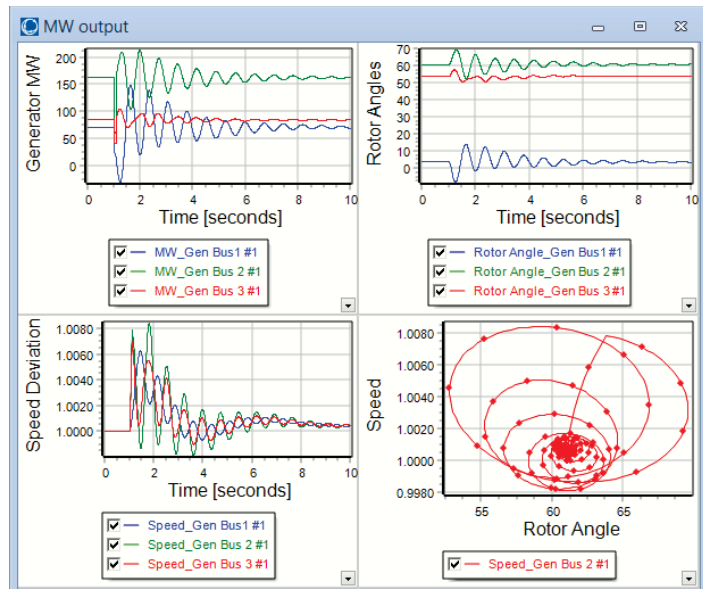
TS9BusCtgEx

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Example: Changing Contingency Elements



- The new events may also be loaded from **TS9ChangeCtg.aux**
- You have now changed what events will be simulated for this Transient Contingency
- Click "Run Transient Stability" to re-run the simulation to simulate a branch fault between Buses 4 and 5 fault located near Bus 5
- The plots should look the same as when you simulated this as a bus fault



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Multiple Contingencies



- In most of the training, we just talk about simulating a single transient contingency event
- Simulator facilitates the definition of multiple transient contingency scenarios within the same case
- These Multiple Transient Contingencies may be defined and simulated, either individually or all together
- Changing the Process Contingencies option from “One Contingency at a time” to “Multiple Contingencies” will change the dialog in small ways throughout
- This will be discussed later

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