

Introduction to PowerWorld Simulator: Interface and Common Tools



I13: Fault Analysis



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Fault Analysis



- Analysis of power system parameters resulting from a ground or line to line fault somewhere in the system
- Simulator contains a tool for analyzing faults in an automatic fashion
- Can perform single and three phase faults
- Faults may be analyzed one at a time or in a batch mode, similar to Simulator's Contingency Analysis

Fault Analysis Dialog



Process Faults in Batch Mode

Fault Analysis

Run Faults Abort

Fault Definitions

- Single Fault
 - Bus Records
 - Lines
 - Generators
 - Loads
 - Switched Shunt Buses
 - Y-Bus Matrices
- Options
- Sequence Data
 - Branches
 - Buses
 - Generators
 - Mutual Impedances
 - Switched Shunts

	Fault Name	Skip	Solved	Fault Object (File Format)	Fault Location	Type for Fault 1	Type for Fault 2	Fault Resistance	Fault Reactance	Fault 1 Current Mag	Fault 1 Current Ang	Fault 1 Thev R	Fault 1 Thev X	Fault 2 Current Mag	Fault 2 Current Ang	Fault 2 Thev R	Fault 2 Thev X
1	Bus '3'	NO	YES	Bus '3'		3PB	SLG	0.000	0.000	6.909	-47.169	0.096	0.107	5.006	-66.519	0.228	0.550
2	Branch '2' 'S' '1'	NO	YES	Branch '2' 'S' '1'	50.0	3PB	SLG	0.000	0.000	7.304	-43.885	0.101	0.094	5.253	-66.317	0.239	0.523
3	B_0000011	NO	YES	Bus '1'		3PB	SLG	0.000	0.000	6.901	-48.163	0.089	0.124	5.327	-63.760	0.203	0.556
4	B_0000022	NO	YES	Bus '2'		3PB	SLG	0.000	0.000	8.520	-41.880	0.085	0.088	6.671	-63.119	0.180	0.432
5	B_0000044	NO	YES	Bus '4'		3PB	SLG	0.000	0.000	7.151	-47.060	0.093	0.105	5.288	-66.495	0.213	0.526
6	B_0000055	NO	YES	Bus '5'		3PB	SLG	0.000	0.000	7.304	-43.885	0.101	0.094	5.253	-66.317	0.239	0.523
7	B_0000066	NO	YES	Bus '6'		3PB	SLG	0.000	0.000	7.738	-41.138	0.097	0.093	5.952	-63.020	0.215	0.478
8	B_0000077	NO	YES	Bus '7'		3PB	SLG	0.000	0.000	7.383	-42.414	0.104	0.095	5.505	-65.205	0.238	0.515

Auto Insert... Load Data... Save Data... Close Help

Process a Single Fault

Fault Analysis

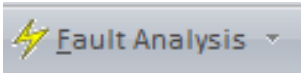


- Fault types include:
 - Single line to ground
 - Line to line
 - Double line to ground
 - Three phase balanced
- The general fault analysis tool can be accessed in run mode by:
Tools ribbon tab → **Fault Analysis**

Example



Open B7FaultExample.pwb

- No sequence data exists, so all fault analysis data fields are set to defaults
- Run the Fault Analysis tool from run mode by: **Tools** ribbon tab
→ **Fault Analysis** 
- Click the **Load Data...** button
 - Confirm replacing sequence data
 - Load B7FaultExample.aux

Sequence Data for Fault Analysis

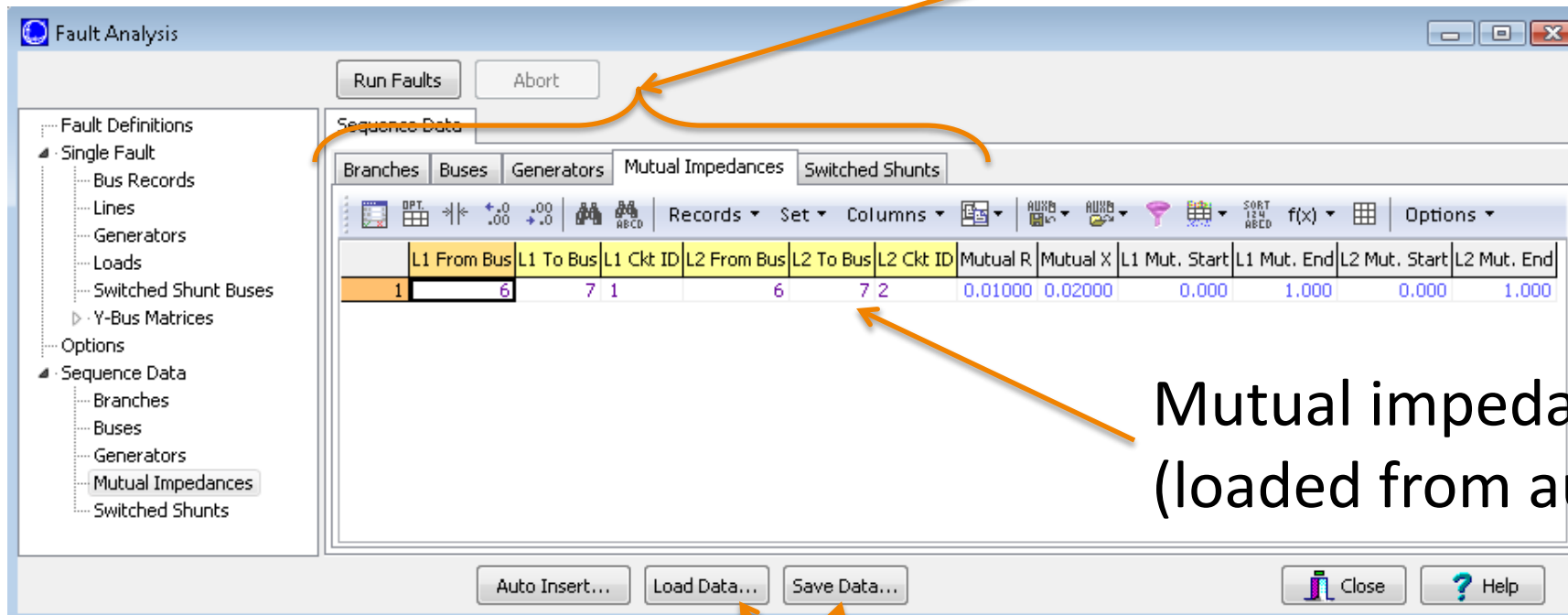


- Formats
 - PowerWorld Auxiliary file (*.aux)
 - PTI Sequence Data file (*.seq)
- Sequence data can similarly be saved to the same types of external files; however, Simulator will store sequence data with the load flow case (*.pwb) if you save the case after loading the sequence data

Fault Dialog: Sequence Data



Specific data for each object type on these tabs



Load and save sequence data as a text file (*.aux or PTI *.seq)

Sequence Data for Fault Analysis



- Simulator defaults zero-sequence parameters to 2.5 times the positive sequence impedances
- PSS/E assumes that elements are open in the zero-sequence model if no zero-sequence data is specified in the *.seq data file
 - When reading in *.seq files, Simulator gives the ability to assume this behavior

Required Sequence Data



- Generators
 - Internal sequence impedances
 - Neutral to ground impedance
- Transmission Lines
 - Zero sequence impedance
 - Zero sequence line shunt admittance
- Transformers
 - Zero sequence impedance and line shunt admittance
 - Phase shifts, entered as Phase in the load flow data
 - Transformer grounding configuration, as a combination of Wye, Grounded Wye, and Delta connections
- Loads
 - Negative and zero sequence load, as an admittance
 - Set on a bus-basis, with admittance given is total admittance for all loads at that bus

Sequence Data for Fault Analysis



- Transmission line mutual impedance (zero sequence mutual impedance between part or all of two transmission lines)
- Fault data for all devices (except mutual impedances) can be entered on the Information Dialogs

Single Fault



- Switch to the **Single Fault** page, and choose Faulted Bus number 3
- Leave as bus fault, single line to ground, zero fault impedance
- Click **Calculate**
 - The case will be solved first to make sure the analysis will be valid
 - The fault analysis calculation is a linearized calculation about the operating point

Fault Dialog: Single Fault



Location and type of fault

Summary Results: Fault Current

Single Fault

Run Faults Abort

Calculate Clear Clear/Close

Choose the Faulted Bus

Sort by ☐ Name ☒ Number

1 (1) [138 kV]
2 (2) [138 kV]
3 (3) [138 kV]
4 (4) [138 kV]
5 (5) [138 kV]
6 (6) [138 kV]

Fault Location
☒ Bus Fault
☐ In-Line Fault

Location %

Fault Type
☒ Single Line-to-Ground
☐ Line-to-Line
☐ 3 Phase Balanced
☐ Double Line-to-Ground

Fault Impedance
R : X :

Fault Current
Scale Current By:
Magnitude: p.u.
Scaled Mag: p.u.
Angle: deg.
Units ☒ p.u. ☐ Amps

Bus Records Lines Generators Loads Switched Shunt Buses Y-Bus Matrices

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	1	0.58122	1.12068	1.09309	4.96	-116.15	131.85
2	2	2	0.60498	1.11853	1.08101	1.18	-118.13	130.25
3	3	3	0.00000	1.15234	1.13231	0.00	-127.06	133.97
4	4	4	0.22810	1.11678	1.09686	-3.19	-124.36	132.04
5	5	5	0.63516	1.08652	1.04222	-6.08	-122.84	125.55
6	6	6	0.77959	1.09499	1.05688	-0.74	-117.57	126.25
7	7	7	0.79294	1.10449	1.05921	-4.43	-121.22	124.79

Auto Insert... Load Data... Save Data... Close Help

Choose faulted device: list depends on location (bus or in-line fault)

Detailed Results: Displayed in the grids on these tabs

Fault Type



- Determines which calculations to perform
 - Single line to ground: assumes phase A to ground
 - Line to line: assumes phase B to phase C
 - Double line to ground: assumes phase B to phase C to ground
 - Three phase balanced
- A non-zero impedance to ground may also be specified; default is 0 (except for line to line)

Single Fault: Results



- Results are displayed on six tab sheets on the **Single Fault** page
 - Per phase bus voltage magnitude (p.u.), angle (deg.), and Thevenin Impedance (at the fault bus, add columns to display)
 - Per phase branch from and to bus current magnitude, with current direction at BOTH ends defined AWAY from the terminal bus
 - Per phase generator current magnitude and angle (deg.), with current direction defined OUT of the generator
 - Per phase load and switched shunt magnitude, with current direction defined AWAY from the terminal bus
 - Y-bus matrices

Visualization of Results



- Fault voltages and currents can be visualized on a oneline diagram
 - On the **Options** page, select a single phase or All Phases from the **Online Display** option group
 - When a single phase or All Phases is selected, Simulator searches for and replaces the following types of text fields on the oneline diagram:

Visualization of Results

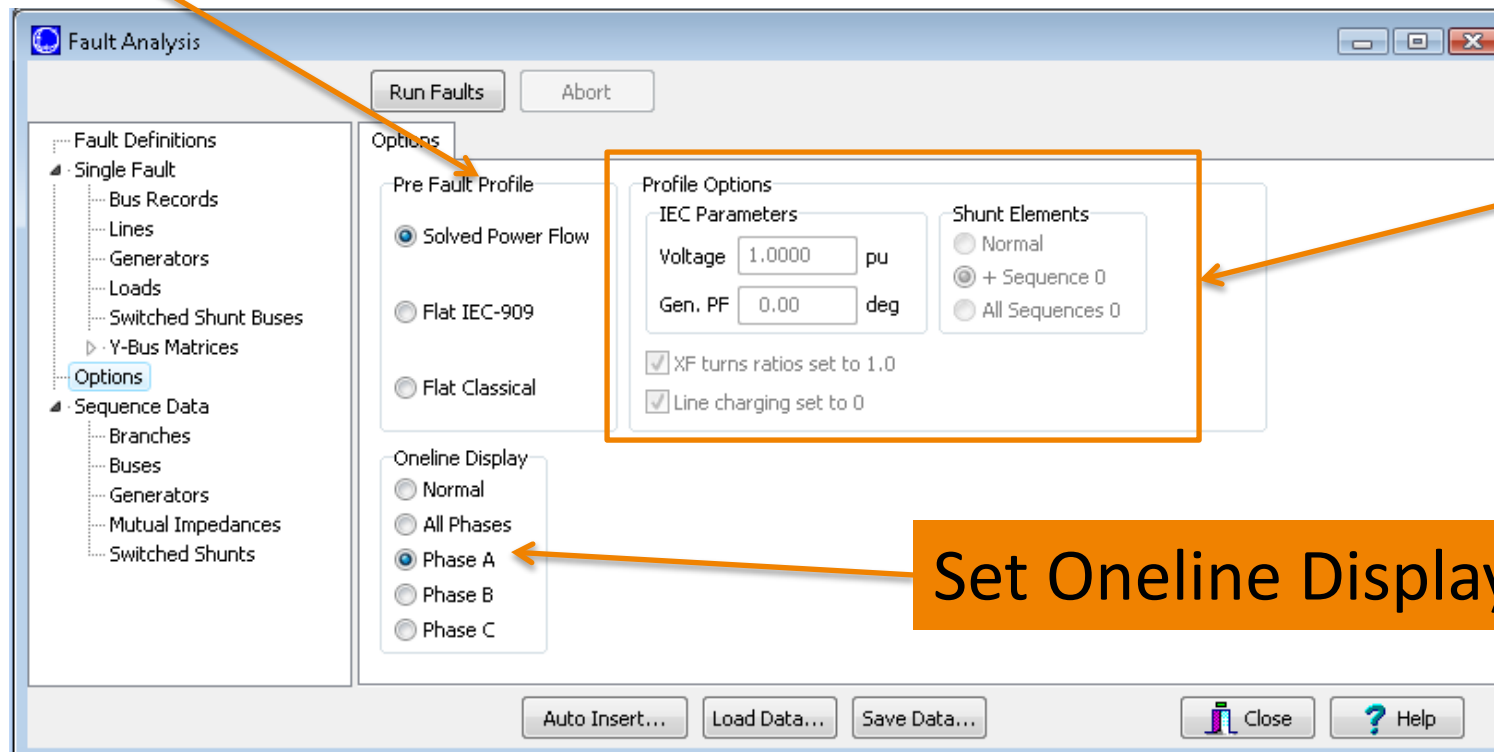


- Bus voltage fields replaced with phase voltage magnitude(s) in p.u.
- Bus angle fields replaced with phase voltage angle(s) in degrees
- Branch MW or Amp fields replaced with phase current magnitude(s) in Amps or p.u., as specified
- Branch MVAR fields replaced with phase current angle(s) in degrees
- Generator MW fields replaced with phase current magnitude(s) in Amps or p.u., as specified
- Generator MVAR fields replaced with phase current angle(s) in degrees

Fault Dialog: Options



Choose Pre-Fault Profile (default is Solved Power Flow); re-calculate fault if changes are made



Enabled Options depend on chosen Pre-Fault Profile

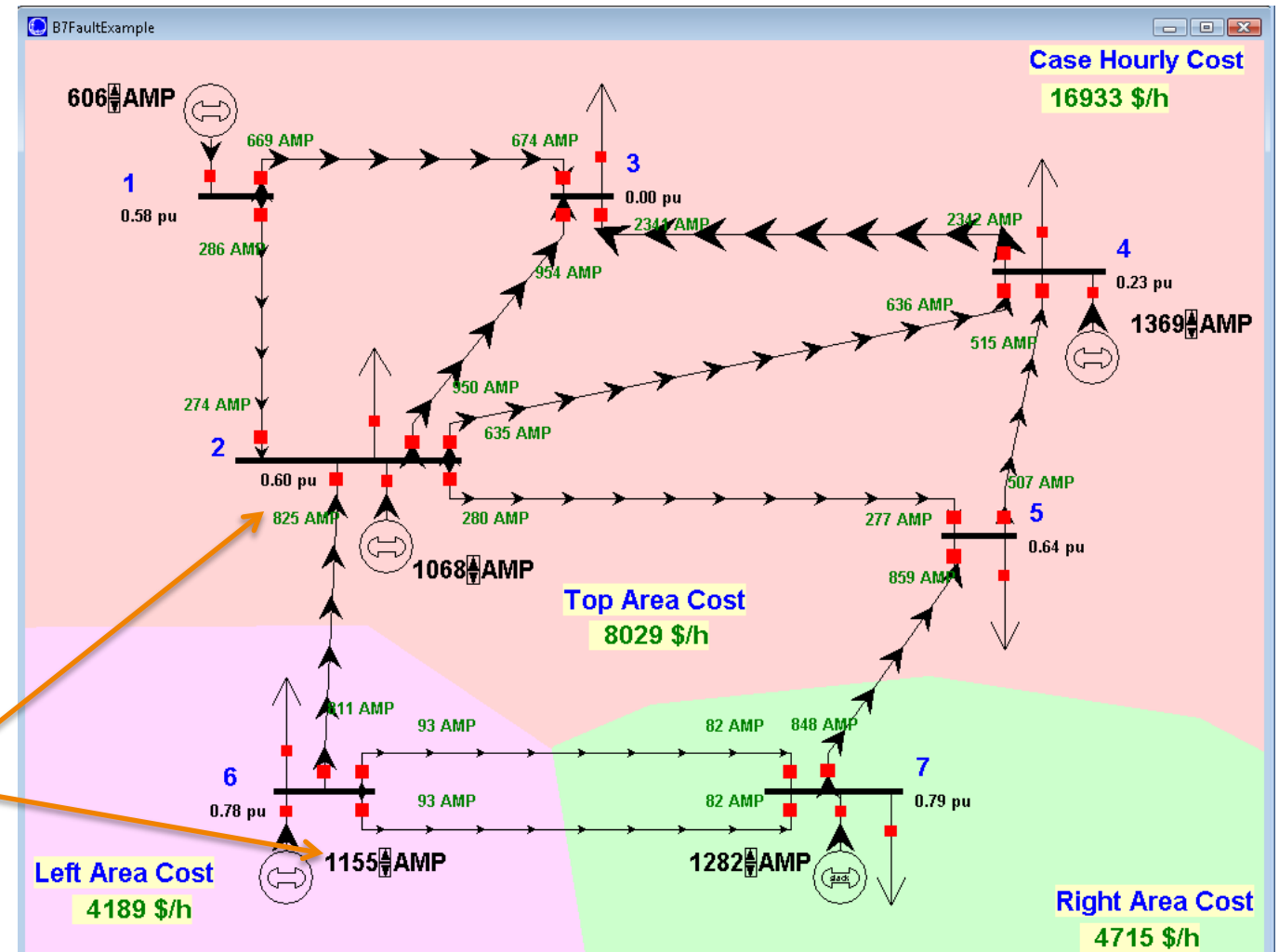
Set Online Display to Phase A

Visualization of Results

Only fields switched to fault analysis results will remain on oneline

Currents shown are magnitude only; would need to include angles to determine direction

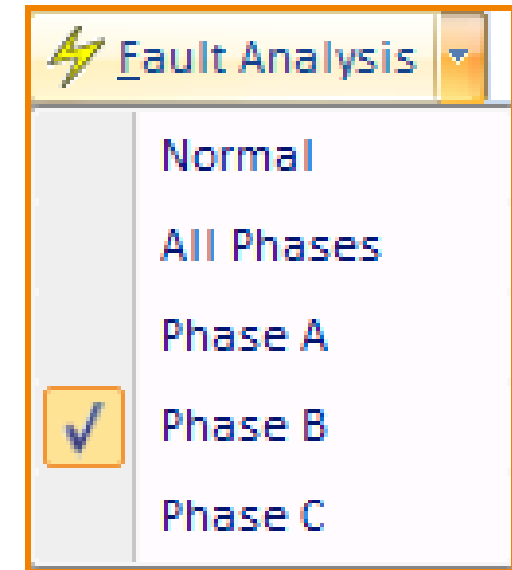
Option on **Single Fault** page to set Units to Amps



Visualization of Results



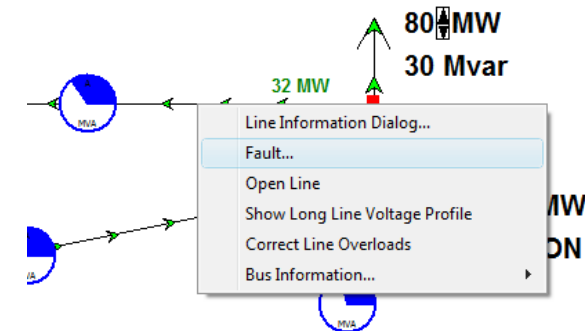
- The phase of the fault data displayed on the diagram can be quickly toggled to a different phase by clicking on the drop-down arrow on the Fault Analysis toolbar button and choosing a new visualization setting



Setting the Fault Location: Bus or In-Line



- Fault Location may be set on the Fault Analysis Dialog → **Single Fault** page
- Alternately, you can right-click on a bus or transmission line on the oneline diagram, and select **Fault...** from the menu to have the fault location fields automatically set
 - Selecting **Fault...** for a bus will set the bus number field
 - Selecting **Fault...** for a transmission line will set the from and to bus numbers, the circuit identifier, and the approximate line location as a percentage of the length of the line
 - Any of these fields can still be changed manually



In-Line Fault



- Calculated based on a location given as a percentage distance from the From end of the line
- Inserts a temporary bus and line segments representing the fault point of the line; reflected on the oneline diagram
- Calculations performed the same as a bus fault at the temporary bus
- Example: set Fault Location as in-line, on the branch between buses 3 and 4, at 50% down the line

In-Line Fault



Location

Single Fault

Calculate Clear Clear/Close

Choose the Faulted Line

Sort by ☐ Name ☒ Number

Search For Near Bus

Select Far Bus, CKT

1 (1) [138 kV]
2 (2) [138 kV]
3 (3) [138 kV]
4 (4) [138 kV]
5 (5) [138 kV]

1 (1) [138 kV] CKT 1
2 (2) [138 kV] CKT 1
4 (4) [138 kV] CKT 1

Fault Type

☒ Single Line-to-Ground
☐ Line-to-Line
☐ 3 Phase Balanced
☐ Double Line-to-Ground

Fault Location

☐ Bus Fault
☒ In-Line Fault

Location % 50

Fault Impedance

R : 0 X : 0.00000

Fault Current

Scale Current By: 1.00000

Magnitude: 3982.270 Amps

Scaled Mag: 3982.270 p.u.

Angle: -77.06 deg.

Units

☐ p.u. ☒ Amps

Bus Records

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C	Total Thev Imp R	Total Thev Imp X
1	1	1	0.58395	1.12010	1.09076	4.63	-116.03	131.92		
2	2	2	0.59614	1.11910	1.08019	0.95	-118.11	130.40		
3	3	3	0.05833	1.13872	1.11988	-4.75	-126.36	133.42		
4	4	4	0.13231	1.12347	1.10698	-3.65	-125.01	132.82		
5	5	5	0.61159	1.08891	1.04384	-6.39	-122.96	125.85		
6	6	6	0.77234	1.09578	1.05647	-0.90	-117.56	126.36		
7	7	7	0.77687	0.57479	0.60807	0.00	180.00	180.00		
8	8	8 FaultPt	0.00000	0.68010	0.78124	0.00	180.00	180.00	0.06386	0.30748

Auto Insert... Load Data... Save Data... Close Help

Fault
Current at
temporary
bus

Temporary
Bus for fault
location

Processing Multiple Faults: Fault Definitions



- Select the **Fault Definitions** page to analyze multiple faults in batch mode, similar to Contingency Analysis
- Click the **Auto-insert...** button
 - Choose **Single-bus** and keep the other defaults
 - Click **Do Insert Fault records**
- Can also insert faults manually
- Line faults have option to use temporary bus to represent fault location

Auto Insert...



- Auto-Insert options similar to those in Contingency Analysis

Save auto-insert options to aux file

Fault Definitions

- Click **Run Faults** Specify location and temporary bus option (In-line faults only) Fault impedance

Units: ☒ p.u. ☐ Amps

☐ Inserts a temporary bus to represent the fault location in a Branch. WARNING: Will make solution slower
Note - If Unchecked: if Fault Location >= 50 then Fault Location = ToBus, else Fault Location = FromBus

	Fault Name	Skip	Solved	Fault Object (File Format)	Fault Location	Type for Fault 1	Type for Fault 2	Fault Resistance	Fault Reactance	Fault Location (Actual)	Fault 1 Current Mag	Fault 1 Current Ang	Fault 1 Subtrans Mag A (pu)	Fault 1 Subtrans Mag B (pu)	Fault 1 Subtrans Mag C (pu)	Fault 1 Thev R	Fault 1 Thev X	Fault 2 Current Mag	Fault 2 Current Ang	Fault 2 Subtrans Mag A (pu)	Fault 2 Subtrans Mag B (pu)
1	B_One	NO	YES	Bus 'One_138.0'		3PB	SLG	0.000	0.000		12.78496	-70.18616	12.785	12.785	12.785	0.01948	0.07978	9.64408	72.25328	9.644	
2	B_Two	NO	YES	Bus 'Two_138.0'		3PB	SLG	0.000	0.000		21.20695	-72.26789	21.207	21.206	21.206	0.01146	0.04768	15.35129	75.86173	15.351	
3	B_Three	NO	YES	Bus 'Three_138.0'		3PB	SLG	0.000	0.000		12.06566	-69.35074	12.066	12.065	12.065	0.02768	0.07748	9.21126	75.00450	9.211	
4	B_Four	NO	YES	Bus 'Four_138.0'		3PB	SLG	0.000	0.000		13.21006	-70.55384	13.210	13.210	13.210	0.02337	0.07200	10.60845	76.07280	10.608	
5	B_Five	NO	YES	Bus 'Five_138.0'		3PB	SLG	0.000	0.000		14.68862	-71.22770	14.689	14.688	14.688	0.02299	0.06456	10.24194	75.78381	10.242	
6	B_Six	NO	YES	Bus 'Six_138.0'		3PB	SLG	0.000	0.000		21.82701	-73.99723	21.827	21.827	21.827	0.01088	0.04639	15.01412	77.44550	15.014	
7	B_Seven	NO	YES	Bus 'Seven_138.0'		3PB	SLG	0.000	0.000		19.91817	-75.35876	19.918	19.918	19.918	0.01320	0.05052	12.84042	79.15186	12.840	

Select 2 different Fault Types; defaults are 3-phase balanced and single line to ground

Results for each fault type

Fault Analysis: Final Notes



- The fault analysis form can be closed while a fault is calculated without clearing the fault; the values will remain in memory until manually cleared or the case is saved or closed
- A Double Line fault automatically uses a Fault Impedance of $999+j999$ and ignores the Fault Impedance settings; use a Double Line to Ground fault to specify a desired Fault Impedance

Fault Analysis: Final Notes



- Before visualizing fault analysis currents in p.u., you may need to first change the number of decimal places for the branch and generator MW and MVAR fields
- Once Sequence Data is loaded from an external file, saving the case file will store the sequence data with the *.pwb as well

Blank Page