Introduction to PowerWorld Simulator: Interface and Common Tools

I13: Fault Analysis

PowerWorld Corporation

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

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

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

Mutual impedance record (loaded from aux)

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.

• PTI assumes that 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.
Sequence Data for Fault Analysis

• Sequence data is required for various devices:
  – Generators
    • Internal sequence impedances
    • Neutral to ground impedance
  – Transmission Lines
    • Zero sequence impedance
    • Zero sequence line shunt admittance
Sequence Data for Fault Analysis

– 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

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

Summary Results: Fault Current

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 **Oneline 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

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

Enabled Options depend on selected Pre Fault Profile

Set Oneline 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

Temporary Bus for fault location

Fault Current at temporary bus
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
Auto Insert...

- Auto-Insert options similar to those in Contingency Analysis

![Auto Insertion of Fault Records](image)

Save auto-insert options to aux file
## Fault Definitions

- **Click Run Faults**

**Specify location** (In-line faults only)

**Fault impedance**

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

**Only specific results available: fault currents and Thevenin impedances**

| Fault Name | 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 Current X | Fault 1 Thev R | Fault 1 Thev X | Fault 2 Current Mag | Fault 2 Current Ang | Fault 2 Current X | Fault 2 Thev R | Fault 2 Thev X |
|------------|--------|----------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-------------------|------------------|-----------------|----------------|----------------|-----------------|-------------------|------------------|----------------|----------------|----------------|
|            |        |                            |                |                 |                 |                 |                 |                   |                  |                 |                 |                 |                   |                   |                  |                 |                 |
| 1_0000001  | NO     | NO, YES Bus '1'            |                | 3PB             | SLG             | 0.000           | 0.000           | 12.88497        | -70.007728       | 0.01948         | 0.02576         | 9.59349        | -72.86082         | 0.06240           | 0.32137         |
| 2_0000002  | NO     | NO, YES Bus '2'            |                | 3PB             | SLG             | 0.000           | 0.000           | 21.206694       | -72.25249        | 0.01146         | 0.04769         | 15.07049       | -77.00230         | 0.03515           | 0.25242         |
| 3_0000003  | NO     | NO, YES Bus '3'            |                | 3PB             | SLG             | 0.000           | 0.000           | 12.05646        | -69.32073        | 0.02720         | 0.07740         | 9.90793        | -76.51295         | 0.07114           | 0.32305         |
| 4_0000044  | NO     | NO, YES Bus '4'            |                | 3PB             | SLG             | 0.000           | 0.000           | 13.21098        | -70.57948        | 0.02327         | 0.07200         | 10.36090       | -77.70316         | 0.05462           | 0.29420         |
| 5_0000055  | NO     | NO, YES Bus '5'            |                | 3PB             | SLG             | 0.000           | 0.000           | 14.88886        | -71.22998        | 0.02299         | 0.06496         | 10.02839       | -77.37022         | 0.07009           | 0.25287         |
| 6_0000066  | NO     | NO, YES Bus '6'            |                | 3PB             | SLG             | 0.000           | 0.000           | 21.82701        | -73.95564        | 0.01088         | 0.04639         | 14.73175       | -78.17741         | 0.03317           | 0.23917         |
| 7_0000077  | NO     | NO, YES Bus '7'            |                | 3PB             | SLG             | 0.000           | 0.000           | 18.51019        | -75.33075        | 0.01320         | 0.05502         | 12.05945       | -80.50408         | 0.04022           | 0.24544         |
| 8_000008    | NO     | NO, YES Bus '8'            |                | 3PB             | SLG             | 0.000           | 0.000           | 12.41607        | -69.37531        | 0.02523         | 0.07582         | 9.51694        | -77.05935         | 0.06396           | 0.32749         |
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.