SATEC

Powerful Solutions

expertmeter™

High Performance Analyzer

PM180

Fault Locator

Application Note

BB0165 Rev. A2

IMPORTANT NOTICE

For accurate fault location, the PM180 must be calibrated under version 31.XX.19 or higher.

REVISION HISTORY

A1	Aug 2015	Initial release
A2	June 2016	Add Two-ended fault location support

Table of Contents

1 General

1.1 Fault Locator Functionality

The PM180 onboard fault locator provides distance to fault information in real-time. It operates on fault events detected and recorded by the PM180 digital fault recorder immediately as events happen.

The fault locator uses impedance-based fault location methods. Distance calculations are based on voltage and current waveforms recorded by the device in response to a detected fault event, and line impedance parameters provided by the user. Impedance calculations use synchronous voltage and current phasors or sequence components depending on the fault location method and the type of a line fault.

Fault locator features:

- Immediate on-line distance to fault and fault impedance information
- Onboard storing of fault distance information that is available for reviewing at any time
- Use on 6 kV to 220 kV overhead power lines
- Single-ended and two-ended fault location methods
- Support for single-circuit and double-circuit (parallel) lines and lines with a transformer branch
- Support for non-homogeneous (multi-segment) lines with non-uniform impedance distribution along the line (single-circuit lines only)

1.2 Off-line Fault Location

As an alternative approach, the supplemental PAS software offers a stand-alone fault locator that can perform fault distance calculations based on voltage and current waveforms retrieved from PM180 devices. It features same options as the PM180 onboard fault locator.

1.3 Single-ended Fault Location

Single-ended fault location is provided by a single device connected to one end of a power line. Single-ended fault location algorithms use one-point measurements and rely on the fault impedance as it is seen from one end of the line. They are highly sensitive to power line characteristics, which exact values are often not known, as well as to the impact of the fault effects caused by mutual coupling and ground fault resistance.

1.4 Two-ended Fault Location

Two-ended fault distance calculations are based on fault data measured by two fault recorders located on both sides of a power line. The devices exchange measured fault information via the Internet, and both make distance calculations using positive or negative-sequence quantities that negate much of the uncertain fault effects.

The two devices exchange measured voltage and current phasors accompanied by precise timestamps to guarantee that both refer to the same event.

For inter-device communications, the devices must be connected to the Ethernet or to a wireless cellular network. UDP port 502 is used for exchange of messages between devices.

Time synchronization of phasors is an important component in accurate distance calculations. Using the GPS time synchronization is highly recommended and is mandatory when communicating via a cellular network. In the event that the communications is provided via the fast Ethernet, guarantied that the message propagation time along the network is stable, the precise clock synchronization is not required as the devices are able to automatically synchronize their local time with the remote device clock via the network.

1.5 Transformer Inaccuracies

The time skew of voltage and current signals contribute large into inaccuracy of distance calculations. This especially concerns customer instrument transformers that may introduce significant phase errors. To minimize the effect of the transformer inaccuracies, follow the instructions below:

1. The device's input voltage and current transformers are carefully calibrated at the factory. In the event the device is provided with a 200-amps DFR module, use it only with the supplied current transformers. Connect the transformers to the input terminals according to the phase marking labels.
2. Use the device transformer correction setup to provide information on customer instrument transformers' errors.
3. If your instrument transformers have significantly non-linear angle error response, use the fault locator transformer correction setup to provide information on transformers phase errors over the entire measurement range.

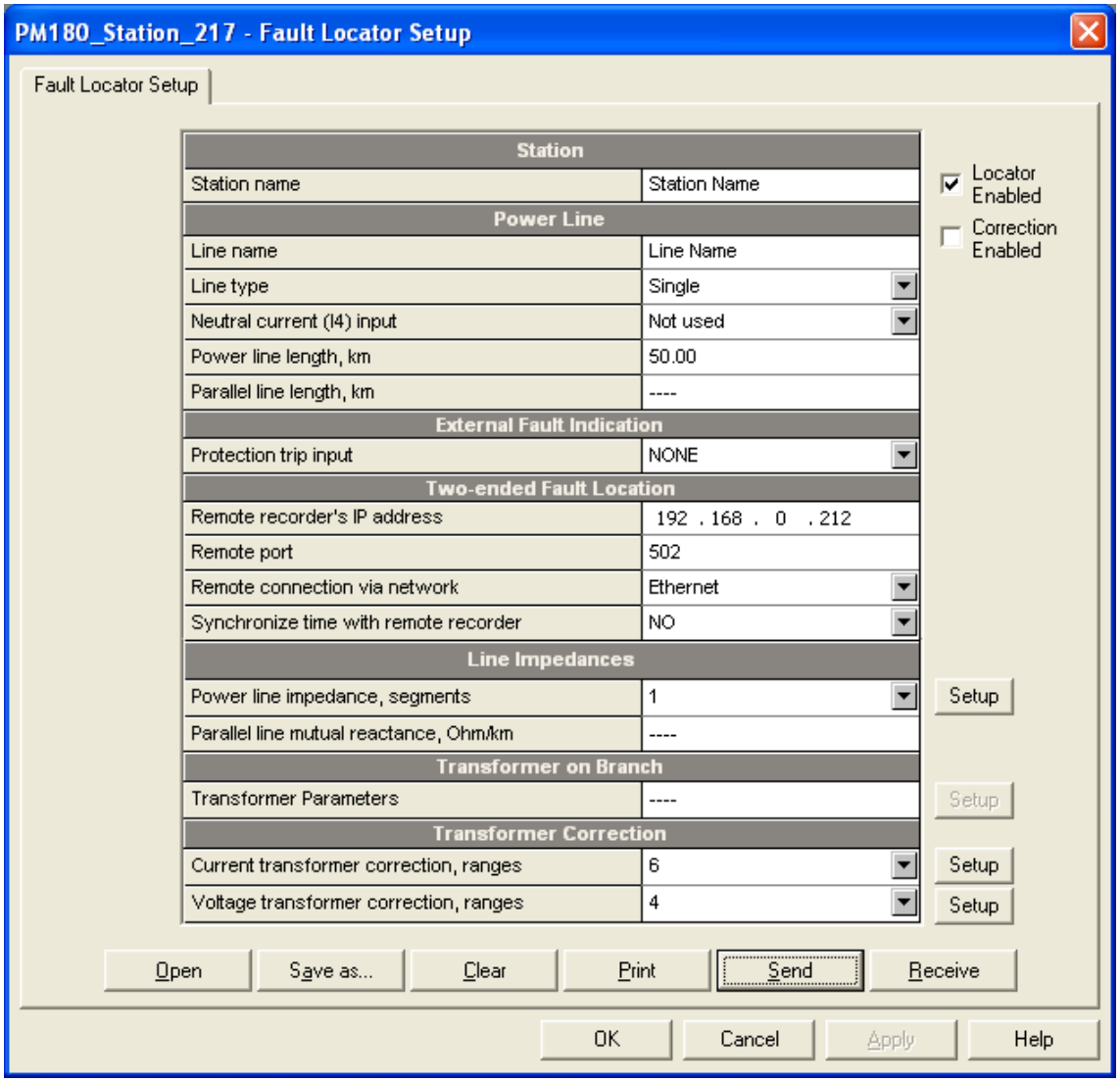
2 Configuring the Device

2.1 Configuring the Fault Locator

2.1.1 General Parameters

To configure the fault locator:

1. Select Fault Locator Setup from the Meter Setup menu.



2. Select desired options.
3. For two-ended fault location, specify the network address and port of the remote device located at the opposite side of a power line. Notice that the remote device is always listening on UDP port 502. If you use another port for communications, ensure that your remote router or firewall makes local remapping to port 502.

   In the event of Ethernet communications between the devices with a stable message propagation time along the network, you can instruct the device to synchronize its local time with the remote device clock via the network before the fault data exchange takes place. This eliminates the need of precise clock synchronization between the devices via GPS.
4. Check the "Locator Enabled" box to enable fault locator operation.

5. Check the "Correction Enabled" box if you want your local transformer correction data to be applied.
6. Click Save as… to store your setup in the device site database, and click Send to send the setup to the device.

See the following table for available options.

Parameter	Options	Default	Description
Station			
Station name	0-15 characters		The name of the station for fault distance reports.
Power Line			
Line name	0-15 characters		The name of the power line for fault distance reports.
Line type	Single line, Parallel (double-circuit) line, Transformer on branch	Single	The type of the power line.
Power line length, km/mile	0-450.00	0	Total length of the power line.
Parallel line length, km/mile (Distance to transformer branch, km/mile)	0-450.00	0	Length of the parallel line for a line with parallel parts, or distance to the branch for a line with a transformer branch.
External Fault Indication			
Protection trip input	None, DI1-DI128	None	A device digital input to which the protection trip signal is connected. Currently not used.
Two-ended Fault Location			
Remote recorder's IP address		0.0.0.0	IP address of the device located at the remote side of the line. Set it to 0.0.0.0 for single-ended fault location calculations.
Remote port	1-65535	502	UDP port of the device located at the remote side of the line.
Remote connection via network	Ethernet, GPRS/Modem	Ethernet	The network (local or cellular) used to communicate with the remote device.
Synchronize time with remote recorder	NO, YES	NO	Enables synchronization of the local time with the remote device clock. Do not use with a cellular network.
Line Impedances			
Power line impedance, segments -> Setup	1-4	1	The number of line segments with different impedances. Click Setup on the right to configure segment impedances.
Parallel line mutual reactance, Ohm/km	0-6.5000	0	Mutual reactance between the parallel lines.
Transformer on Branch			
Transformer parameters -> Setup			Parameters of the power transformer on the line branch. Click Setup on the right to configure the transformer parameters.
Transformer Correction			
Current transformer correction, ranges -> Setup	1-6	1	The number of correction points within the transformer's current rating. Click Setup on the right to configure transformer ratio correction factors and phase angle errors.

Parameter	Options	Default	Description
Voltage transformer correction, ranges -> Setup	1-4	1	The number of correction points within the transformer's voltage rating. Click Setup on the right to configure transformer ratio correction factors and phase angle errors.

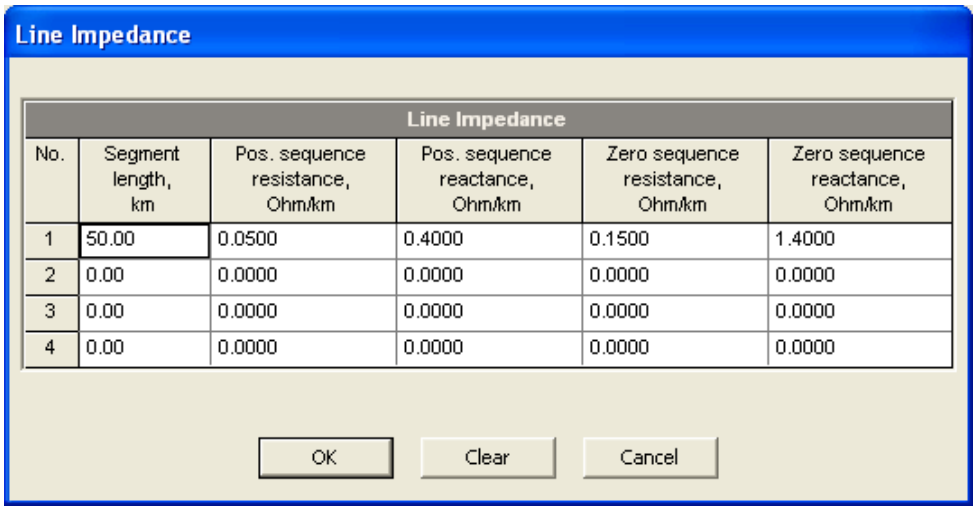
NOTE:

To select the preferred distance units (km/mile), click on Tools at the menu bar, select Options/Preferences and then check the desired distance units.

2.1.2 Power Line Impedance

To setup the power line impedance:

1. In the Power line impedance row, select the number of line segments with different line characteristics.
2. Click Setup on the right of the row to setup line segments.



3. Specify the line segment length, and positive and zero sequence impedances of the segment. More precise line impedance data you provide here, more accurate distance to fault calculation results may be achieved.
4. For a line with multiple segments (non-homogeneous line), specify the segment length and impedances for each line segment with different line characteristics. The sum of the segment lengths should be equal to the total power line length you defined in the power line parameters.
5. Click OK to apply your new setup.

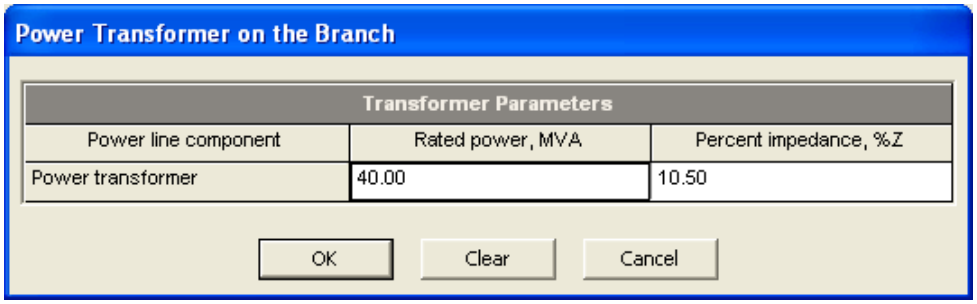
NOTE:

Multiple segments are not supported for double-circuit (parallel) lines and lines with a branch.

2.1.3 Line with Branch

For a line with a transformer branch, setup the power transformer parameters:

1. Click Setup on the right of the Transformer Parameters row.



2. Specify the transformer rated power and percent impedance.
3. Click OK to apply your new setup.

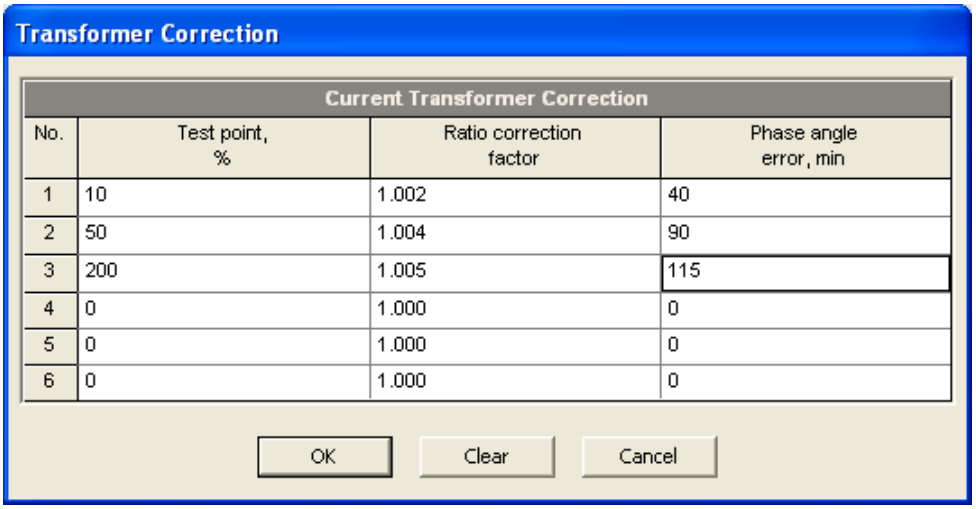
2.1.4 Transformer Correction

Generally, the PM180 provides a common transformer correction setup option that is used for compensation of instrument transformer ratio and phase angle errors in all device measurements (see MeterSetup/General Setup/Transformer Correction in PAS).

As the transformer angle errors highly affect accuracy of the distance calculations, the fault locator setup gives you an additional option for precise multi-point transformer error correction you can use to improve accuracy of the calculated distance.

To setup the transformer correction parameters:

1. In the Current/Voltage transformer correction row, select the number of ranges (test points) with different correction coefficients.
2. Click Setup on the right of the row to setup correction parameters.



3. For each range, specify the required test point level, transformer ration correction factor and phase angle error. A test point is given in percent of the rated current/voltage, below which the correction coefficients are to be applied.

   The last non-zero test point's parameters are applied both below and above the specified level. To use a single point correction over the whole measurement range, specify any non-zero test point level.

4. Click OK to apply your new setup.

NOTE:

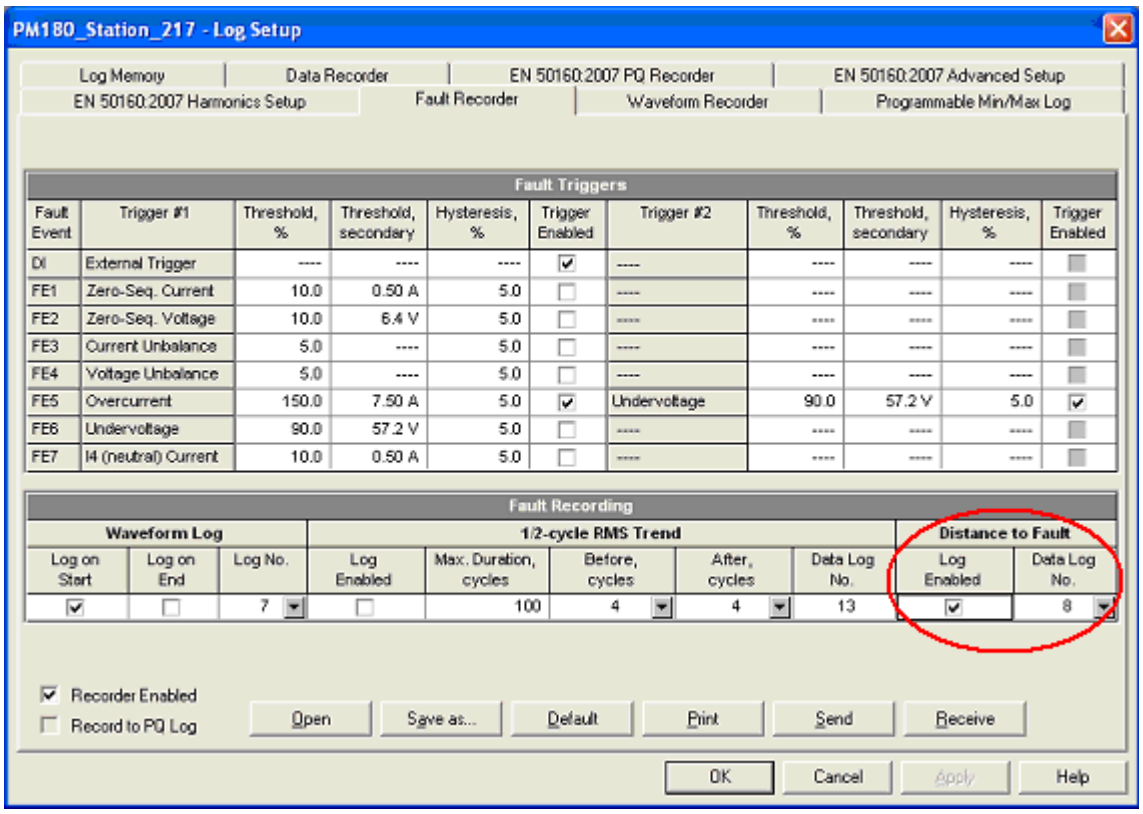
Your settings will not be in effect unless the "Correction Enabled" box on the locator setup tab is checked.

2.2 Configuring the Fault Recorder

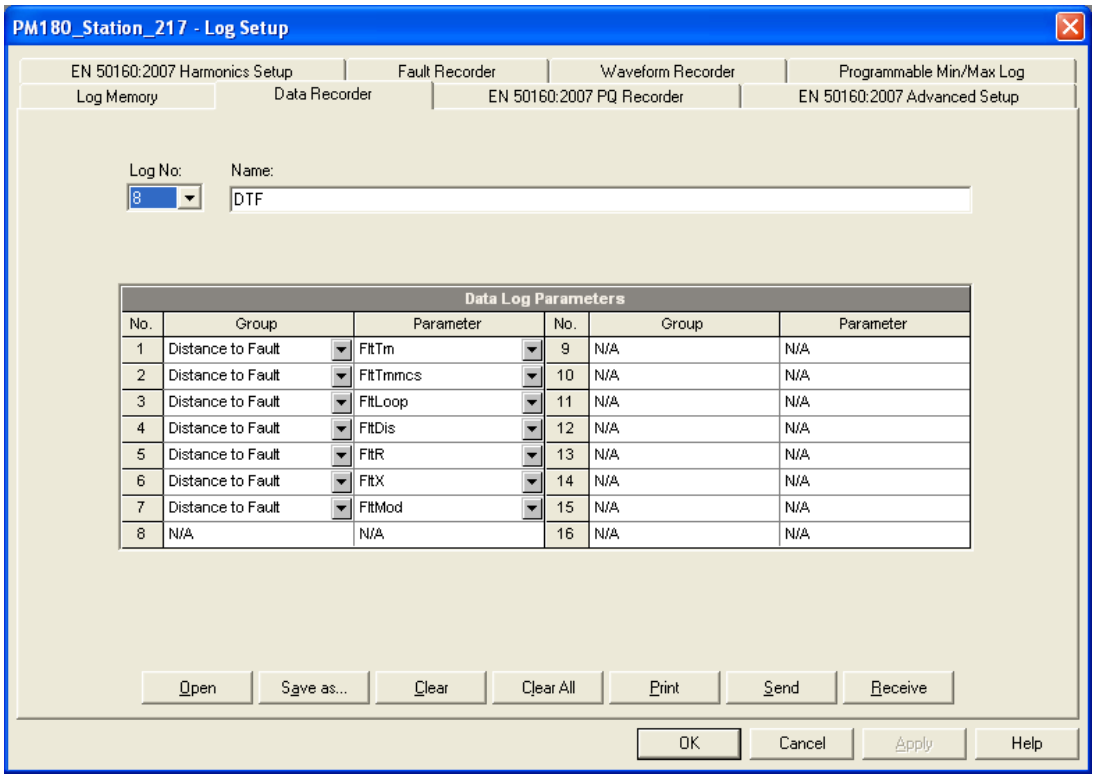
Before operating the fault locator, configure the device fault recorder and files you will use for recording fault waveforms and distance calculation results. For more information, see "Configuring the Fault Recorder" in the PM180 Operation Manual.

For proper operation of the fault locator:

1. Configure the fault triggers to be used for detecting line faults.
2. Select the waveform log for recording fault waveforms. See "Configuring the Waveform Recorder" in the PM180 Operation Manual for details. Use a 64 or more samples-per-cycle rate for accurate distance calculations.
3. Select a data log for recording distance calculations results and check the Log Enabled box to allow data recording.



4. For recording distance calculations results, allocate the memory and configure a data log file as shown in the picture below. See "Configuring the Device Memory" and "Configuring the Data Recorder" in the PM180 Operation Manual for more information on configuring the data recorder.



Refer to the table in the following section for explanation of the distance to fault parameters.

3 Operating the Onboard Fault Locator

3.1 Fault Locator Operation

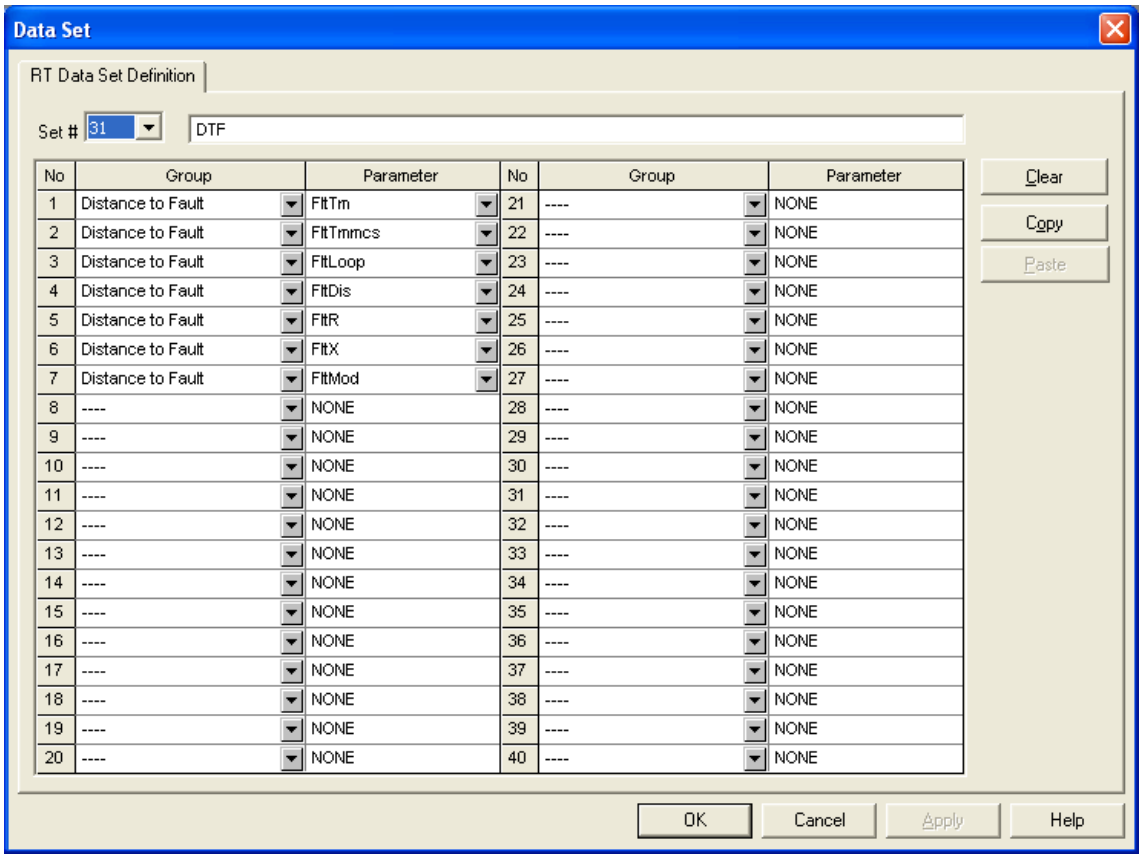
When fault locator operation is enabled, the fault recorder automatically launches the fault locator as a fault is detected. It may take a short time while the voltage and current waveforms are completely recorded to the waveform log file and distance calculation results are updated and recorded to the device data log.

In case of two-ended fault location, it will take additional time for the two devices to locally qualify the fault and make the required calculations, and then to exchange data between the devices and finally calculate the fault distance.

In the event a remote device is not available, or the measured fault phasors do not match locally calculated data, or two-ended calculations may not provide reliable results, the fault locator uses single-ended location algorithms and indicates locally calculated distance to fault. The fault location method it used is indicated along with the distance calculation results.

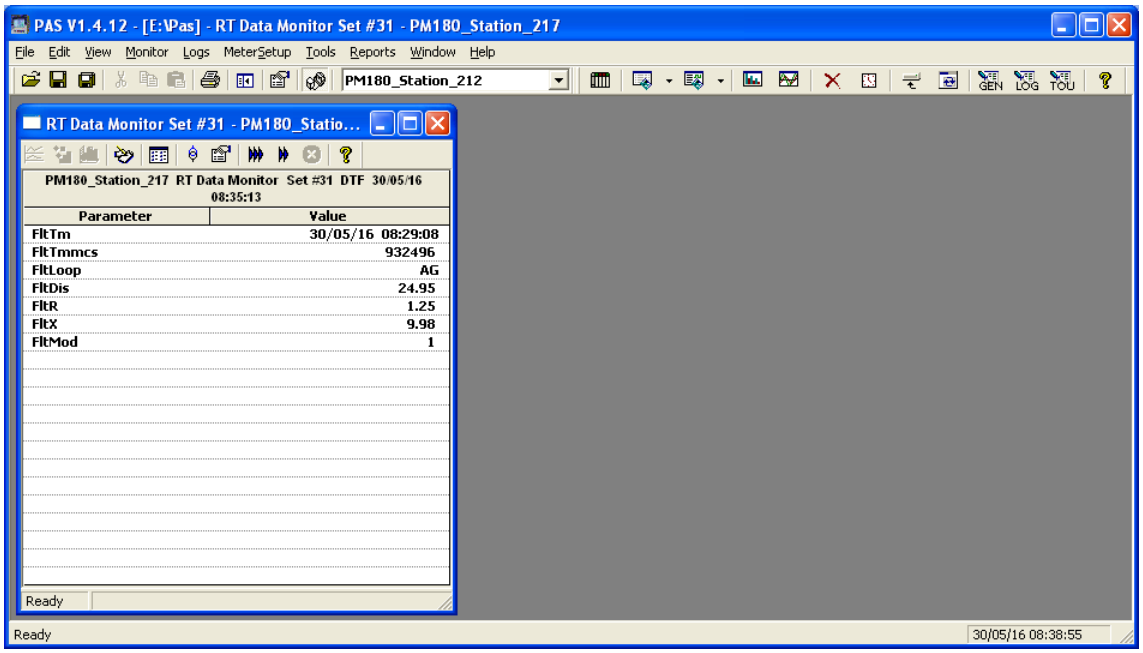
3.2 Getting On-Line Data

Distance calculation results can be read on-line via the PAS Data Monitor. Configure a Data Set for monitoring the "Distance to Fault" data group and get on-line data as shown in the pictures below.



No	Group	Parameter	No	Group	Parameter
1	Distance to Fault	FltTm	21	----	NONE
2	Distance to Fault	FltTmmcs	22	----	NONE
3	Distance to Fault	FltLoop	23	----	NONE
4	Distance to Fault	FltDis	24	----	NONE
5	Distance to Fault	FltR	25	----	NONE
6	Distance to Fault	FltX	26	----	NONE
7	Distance to Fault	FltMod	27	----	NONE
8	----	NONE	28	----	NONE
9	----	NONE	29	----	NONE
10	----	NONE	30	----	NONE
11	----	NONE	31	----	NONE
12	----	NONE	32	----	NONE
13	----	NONE	33	----	NONE
14	----	NONE	34	----	NONE
15	----	NONE	35	----	NONE
16	----	NONE	36	----	NONE
17	----	NONE	37	----	NONE
18	----	NONE	38	----	NONE
19	----	NONE	39	----	NONE
20	----	NONE	40	----	NONE

See "Viewing Real-time Data" in the PM180 Operation Manual for more information on configuring data sets and reading on-line data from the device.



See the following table for explanation of the fault distance parameters.

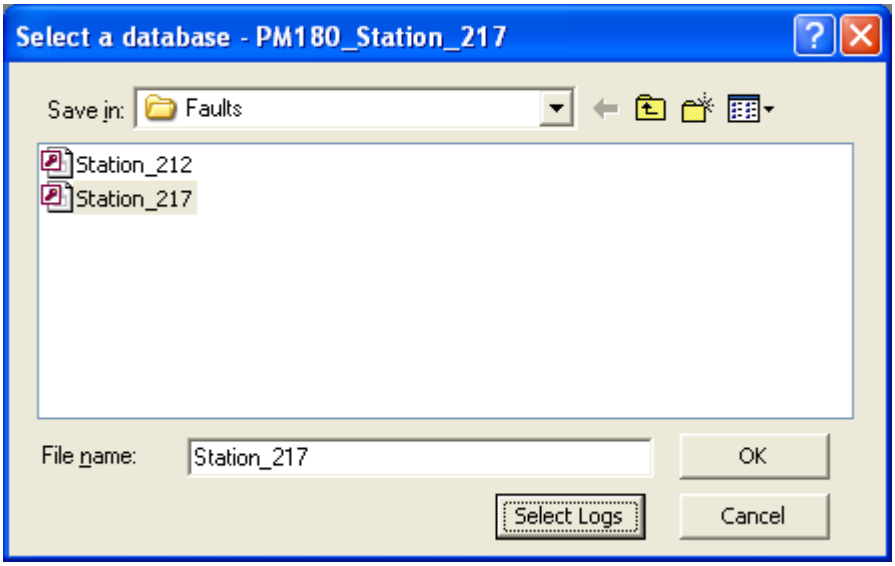
Name	Description	Value
FltTm	Fault time	
FltTmmcs	Fault time, fractional seconds in µs	
FltLoop	Fault loop type	Und = undefined loop AG = phase A to ground BG = phase B to ground CG = phase C to ground AB = phase A to phase B BC = phase B to phase C CA = phase C to phase A ABG = phases A and B to ground BCG = phases B and C to ground CAG = phases C and A to ground ABC = tree-phase loop
FltDis	Fault distance, km/mi	
FltR	Fault resistance, Ohm	
FltX	Fault reactance, Ohm	
FltMod	Fault location mode/status	0 = single-ended fault location 1 = two-ended fault location 2 = forced single-ended location (remote unit didn't respond) 3 = forced single-ended location (no remote match found) 4 = forced single-ended location (unsuccessful two-ended location)

3.3 Getting Recorded Data

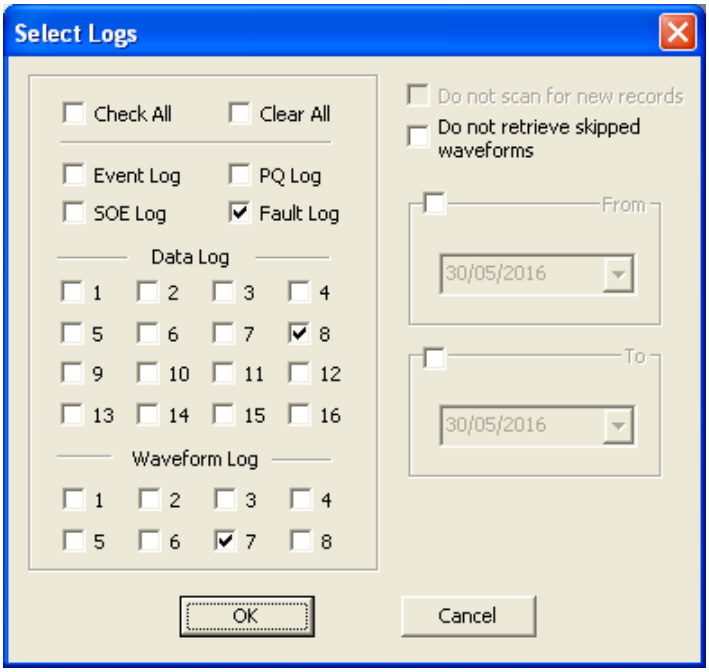
See "Retrieving Recorded Data" in the PM180 Operation Manual for more information on uploading files from the device and storing them on your PC.

To retrieve the recorded fault data from the device:

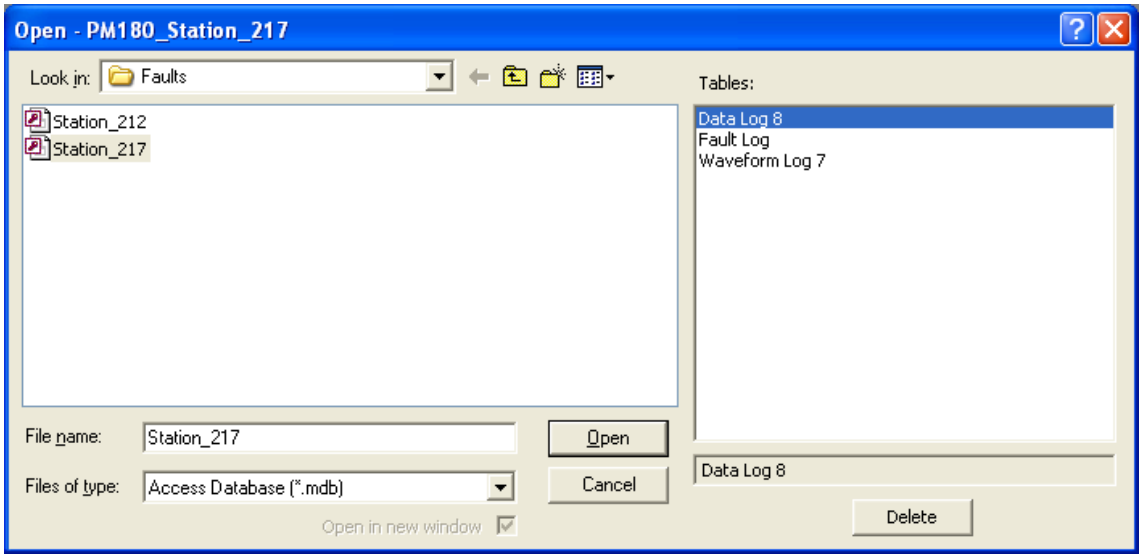
1. Ensure you have your device site selected on the PAS toolbar.
2. Select "Upload Logs" from the Logs menu or click on the "Upload log files" icon on the PAS toolbar.
3. Select a folder for storing your log files and either point to an existing database, or type a name for a new database where the data would be stored.



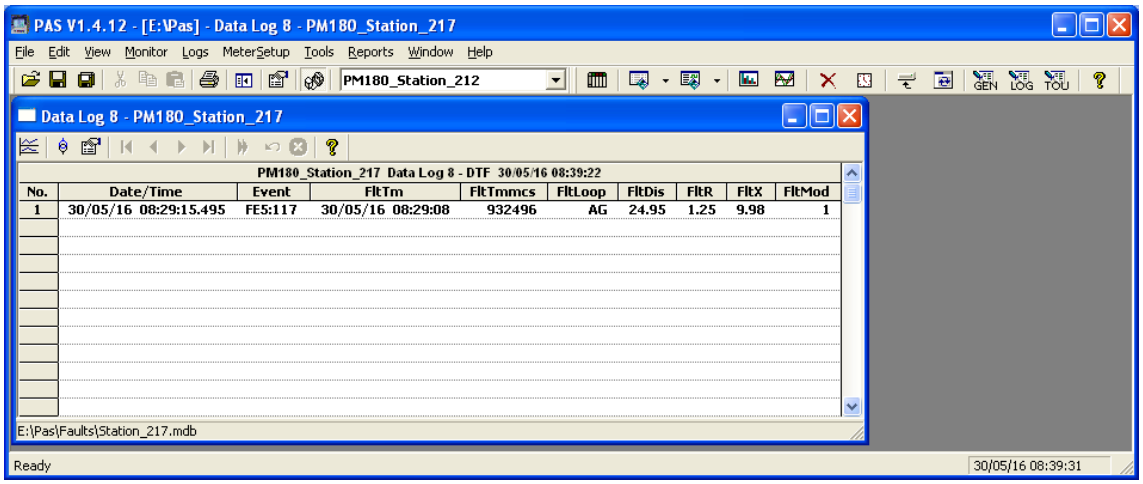
4. Click "Select Logs" and check the fault log box, and the boxes for the data and waveform log files you selected for recording fault waveforms and distance calculations results in the Fault Recorder setup.



To view the recorded fault distance data, select Open… in the File menu, point to the database with the uploaded data and double click on the data log table on the right pane.



See "Viewing the Data Log" in the PM180 Operation Manual for more information on data viewing options.

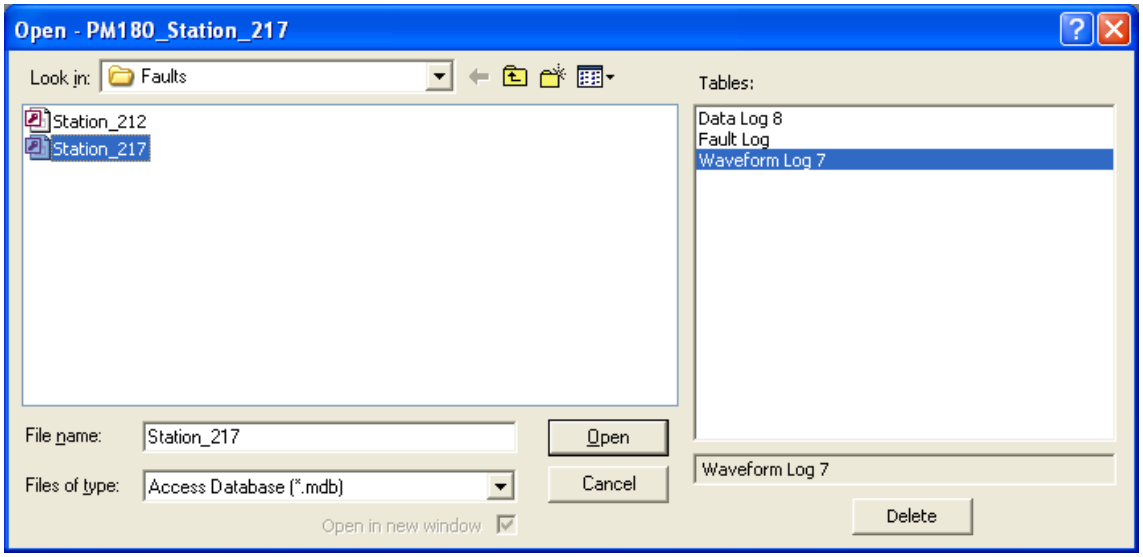


4 Using the Off-line Fault Locator

4.1 Single-ended Fault Location

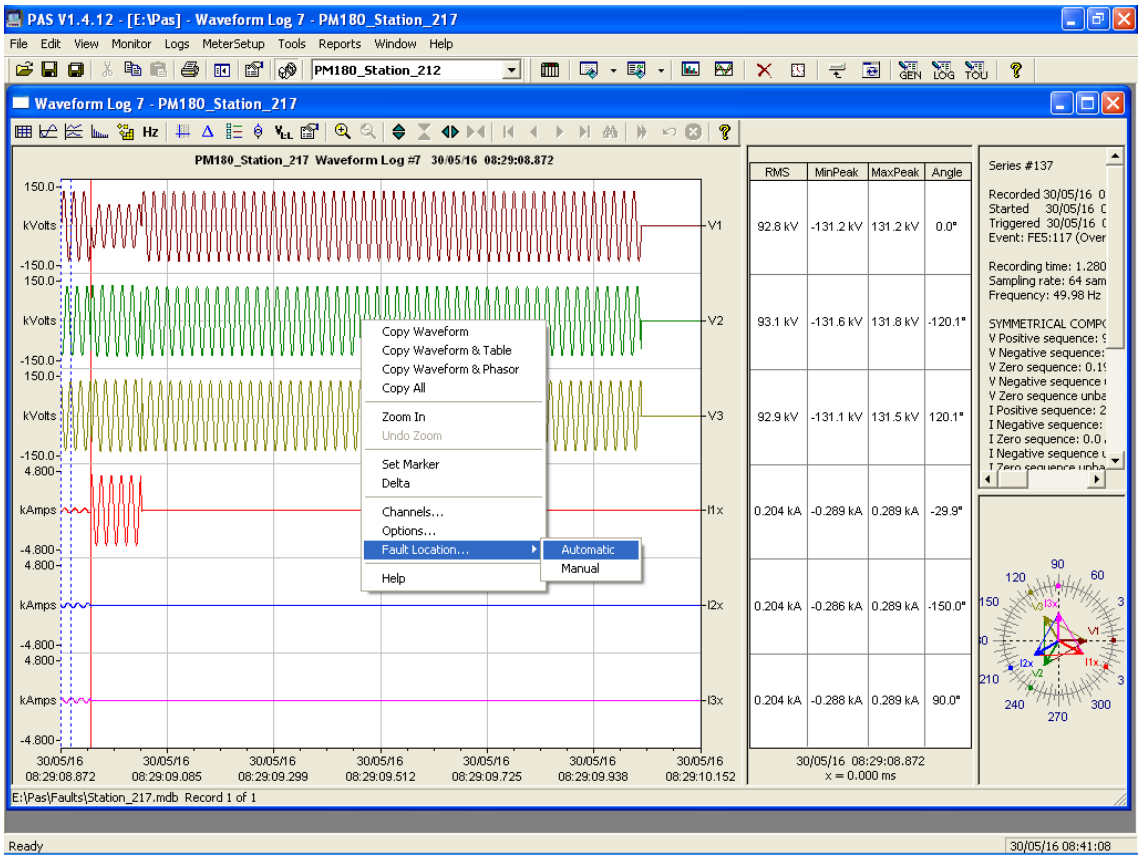
For off-line single-ended fault location:

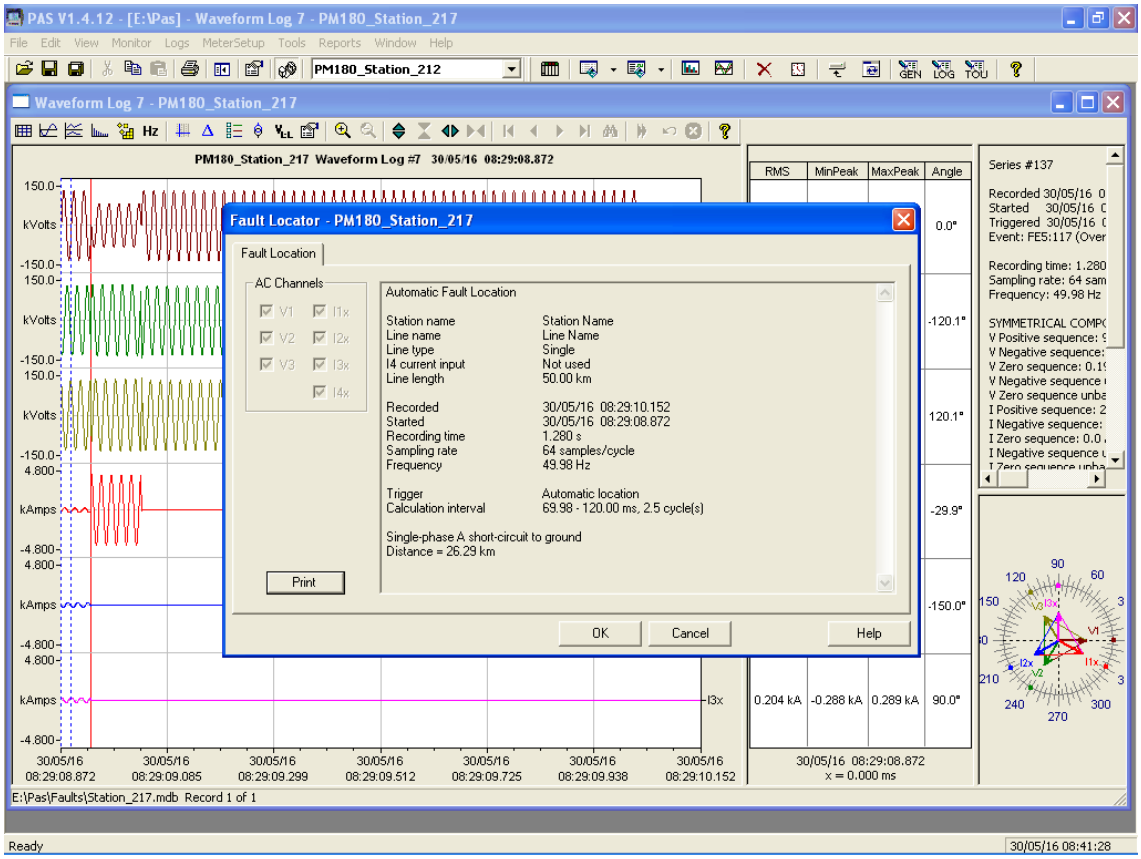
1. Retrieve the fault waveform log file from your device as shown in section "Getting Recorded Data" above.
2. Select Open… in the File menu, point to the database with the uploaded data and double click on the waveform log table on the right pane.



3. Select a fault waveform for which you want to calculate the fault distance. See "Viewing Waveforms" in the PM180 Operation Manual for more information on viewing options.
4. Click on the waveform window with the right mouse button, point to "Fault Location" and select "Automatic".
5. If you wish to manually locate the fault window for distance calculations, point with the mouse to the left dashed marker line and drag it to the place where the window is to begin, then click on the waveform with the right mouse button, point to "Fault Location" and select "Manual".

The distance calculation results are indicated as shown in the picture below. Click on Print if you wish to get a printed copy of the results.

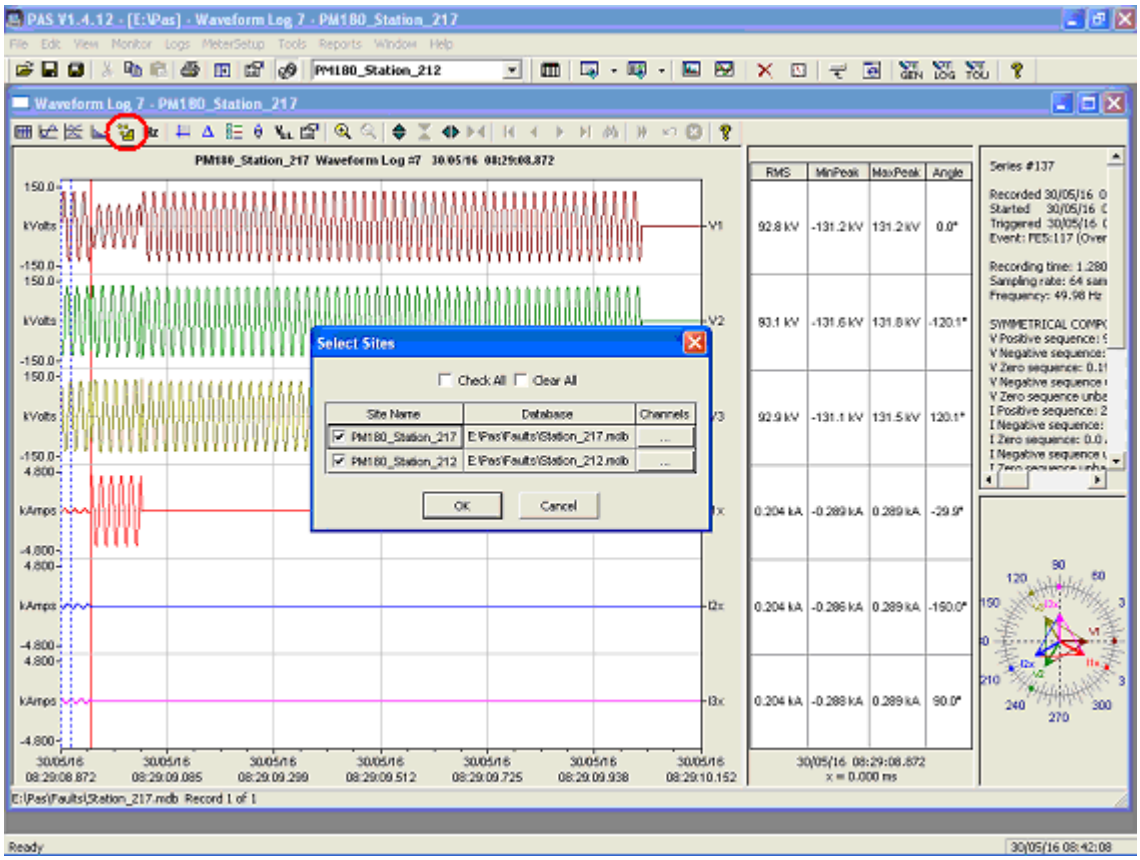

PAS V1.4.12 - [E:\Pas] - Waveform Log 7 - PM180_Station_217
File Edit View Monitor Logs MeterSetup Tools Reports Window Help
PM180_Station_212
Waveform Log 7 - PM180_Station_217
PM180_Station_217 Waveform Log #7 30/05/16 08:29:08.872
RMS MinPeak MaxPeak Angle
92.8 kV -131.2 kV 131.2 kV 0.0°
93.1 kV -131.6 kV 131.8 kV -120.1°
92.9 kV -131.1 kV 131.5 kV 120.1°
0.204 kA -0.289 kA 0.289 kA -29.9°
0.204 kA -0.286 kA 0.289 kA -150.0°
0.204 kA -0.288 kA 0.289 kA 90.0°
Copy Waveform
Copy Waveform & Table
Copy Waveform & Phasor
Copy All
Zoom In
Undo Zoom
Set Marker
Delta
Channels...
Options...
Fault Location...
Automatic
Manual
Help
Series #137
E:\Pas\Faults\Station_217.mdb Record 1 of 1
Ready
30/05/16 08:41:08


PAS V1.4.12 - [E:\Pas] - Waveform Log 7 - PM180_Station_217
Fault Locator - PM180_Station_217
Fault Location
AC Channels
V1 I1x
V2 I2x
V3 I3x
I4x
Automatic Fault Location
Station name Station Name
Line name Line Name
Line type Single
I4 current input Not used
Line length 50.00 km
Recorded 30/05/16 08:29:10.152
Started 30/05/16 08:29:08.872
Recording time 1.280 s
Sampling rate 64 samples/cycle
Frequency 49.98 Hz
Trigger Automatic location
Calculation interval 69.98 - 120.00 ms, 2.5 cycle(s)
Single-phase A short-circuit to ground
Distance = 26.29 km
Print
OK
Cancel
Help
E:\Pas\Faults\Station_217.mdb Record 1 of 1
Ready
30/05/16 08:41:28

4.2 Two-ended Fault Location

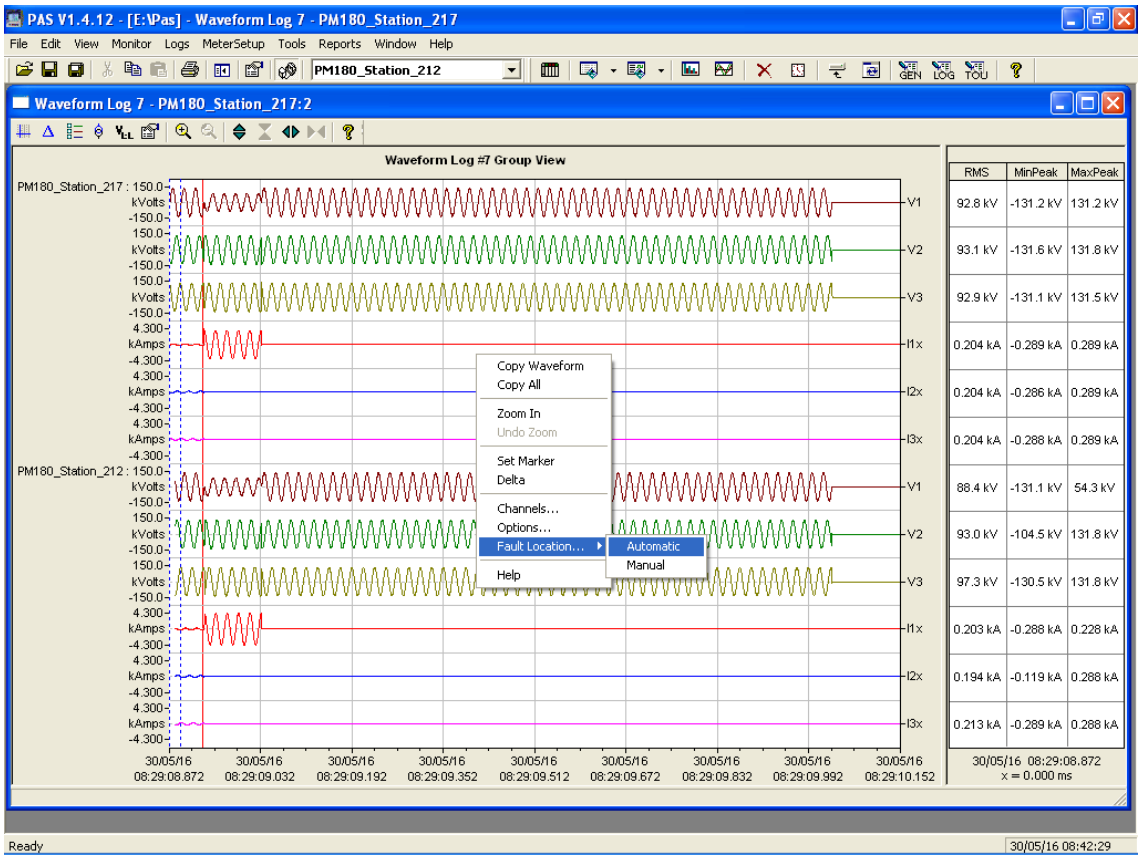
For two-ended fault location:

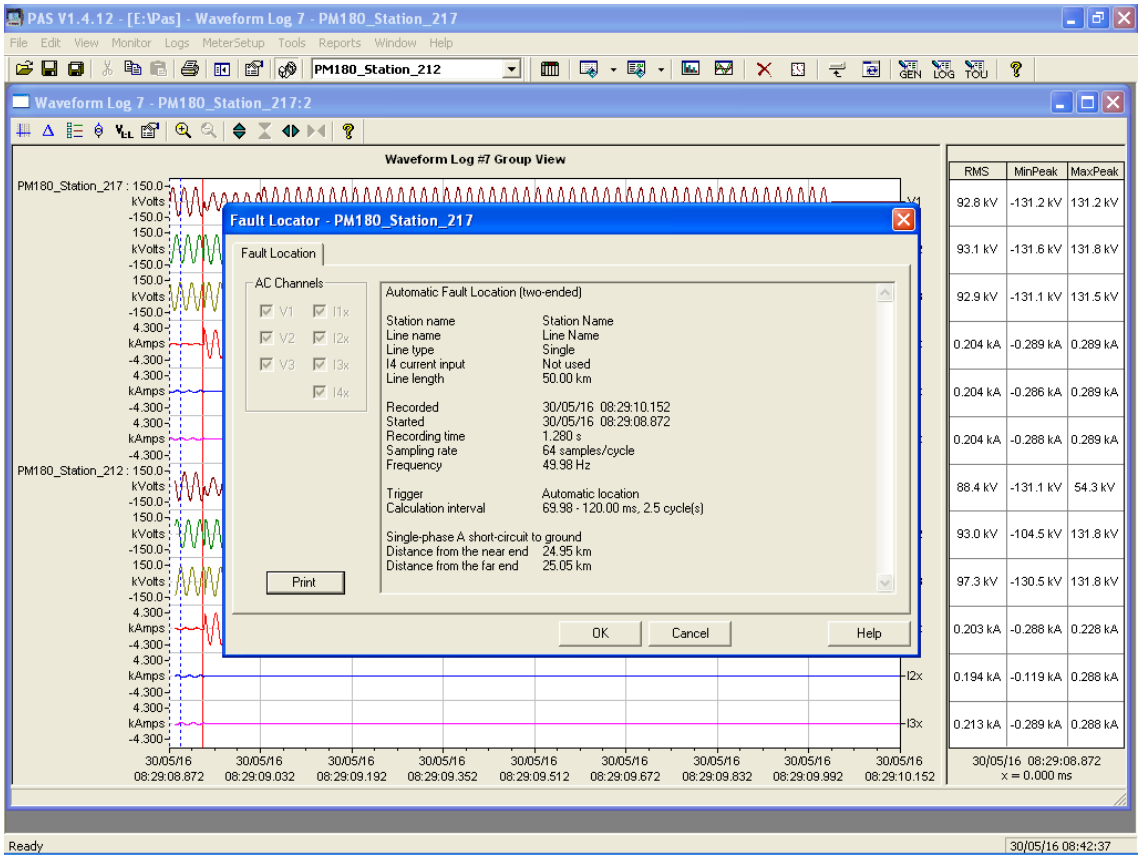
1. Retrieve the fault waveform log files from both devices located on two sides of the power line as shown in section "Getting Recorded Data" above. Put both databases with the retrieved data to the same folder.
2. Select Open… in the File menu, point to one of the databases with the uploaded data and double click on the waveform log table on the right pane.
3. Select a fault waveform for which you want to calculate the fault distance. See "Viewing Waveforms" in the PM180 Operation Manual for more information on viewing options.
4. Click on the Multi-site View icon on the PAS toolbar (surrounded by red circle in the picture below). PAS scans through the databases for waveforms that match in time with the selected waveform and shows a list of events for which such a match is found.



5. Check the two-sided waveforms to be uses for distance calculations. You can also select the waveform channels you want to view for each site by clicking the button on the right to the site. An example of two synchronized waveforms is shown in the picture below.
6. Click on the waveform with the right mouse button, point to "Fault Location" and select "Automatic".
7. If you wish to manually locate the fault window for distance calculations, point with the mouse to the left dashed marker line and drag it to the place where the window is to begin, then click on the waveform with the right mouse button, point to "Fault Location" and select "Manual".

The distance calculation results are indicated as shown in the picture below. Click on Print if you wish to get a printed copy of the results.


PAS V1.4.12 - [E:\Pas] - Waveform Log 7 - PM180_Station_217
File Edit View Monitor Logs MeterSetup Tools Reports Window Help
PM180_Station_212
Waveform Log 7 - PM180_Station_217:2
Waveform Log #7 Group View
PM180_Station_217 : 150.0 kVolts
PM180_Station_212 : 150.0 kVolts
4.300 kAmps
V1
V2
V3
I1x
I2x
I3x
Copy Waveform
Copy All
Zoom In
Undo Zoom
Set Marker
Delta
Channels...
Options...
Fault Location...
Automatic
Manual
Help
RMS MinPeak MaxPeak
92.8 kV -131.2 kV 131.2 kV
93.1 kV -131.6 kV 131.8 kV
92.9 kV -131.1 kV 131.5 kV
0.204 kA -0.289 kA 0.289 kA
0.204 kA -0.286 kA 0.289 kA
0.204 kA -0.288 kA 0.289 kA
88.4 kV -131.1 kV 54.3 kV
93.0 kV -104.5 kV 131.8 kV
97.3 kV -130.5 kV 131.8 kV
0.203 kA -0.288 kA 0.228 kA
0.194 kA -0.119 kA 0.288 kA
0.213 kA -0.289 kA 0.288 kA
30/05/16 08:29:08.872
30/05/16 08:29:09.032
30/05/16 08:29:09.192
30/05/16 08:29:09.352
30/05/16 08:29:09.512
30/05/16 08:29:09.672
30/05/16 08:29:09.832
30/05/16 08:29:09.992
30/05/16 08:29:10.152
30/05/16 08:29:08.872
x = 0.000 ms
Ready
30/05/16 08:42:29


PAS V1.4.12 - [E:\Pas] - Waveform Log 7 - PM180_Station_217
Waveform Log 7 - PM180_Station_217:2
Waveform Log #7 Group View
Fault Locator - PM180_Station_217
Fault Location
AC Channels
V1 V2 V3 I1x I2x I3x I4x
Automatic Fault Location (two-ended)
Station name Station Name
Line name Line Name
Line type Single
I4 current input Not used
Line length 50.00 km
Recorded 30/05/16 08:29:10.152
Started 30/05/16 08:29:08.872
Recording time 1.280 s
Sampling rate 64 samples/cycle
Frequency 49.98 Hz
Trigger Automatic location
Calculation interval 69.98 - 120.00 ms, 2.5 cycle(s)
Single-phase A short-circuit to ground
Distance from the near end 24.95 km
Distance from the far end 25.05 km
Print
OK
Cancel
Help
RMS MinPeak MaxPeak
30/05/16 08:29:08.872
x = 0.000 ms
Ready
30/05/16 08:42:37