

Expediting Service Restoration with an Automated Fault Location System

by

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Outline

- Real-time automated fault location and analysis
- Limitations of traditional methods
- WebFL system architecture & data requirements
- Result delivery and notification
- Key benefits



Real-time fault location & analysis

- Gaining competitive advantage in the marketplace
 - Save costs
 - Improve reliability, efficiency, customer satisfactions
- Conventional tools no longer satisfying the requirements under new environment
 - Real-time monitoring, analysis, and visualization
 - Enterprise-wide access to information (not just data)



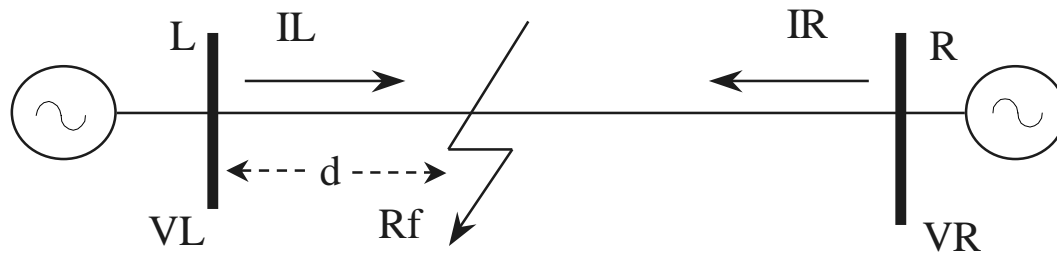
Real-time fault location & analysis

- System operators
 - Decision support tool
 - Faster service restoration: SAIDI & SAIFI
 - Improved situational awareness
- Protection (analysis) engineers
 - Improve productivity
 - Avoid time-consuming analysis of system conditions
 - Receive information in a timely manner
- Asset management
 - Optimize the availability of transmission infrastructure
 - Minimize helicopter patrolling area

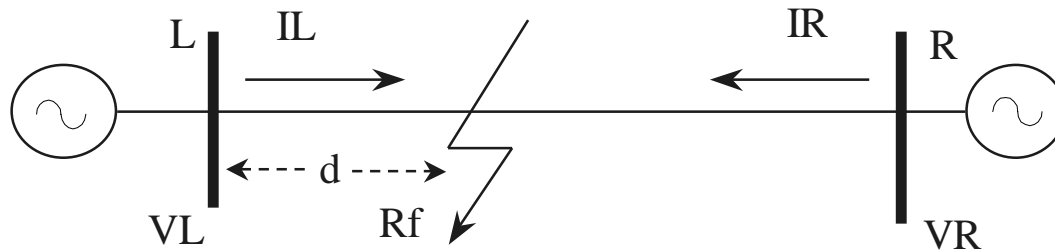


Limitations of traditional methods

- Lack of network-wide analysis capability
- Limited accuracy – relying on various assumptions



Limitations of traditional methods

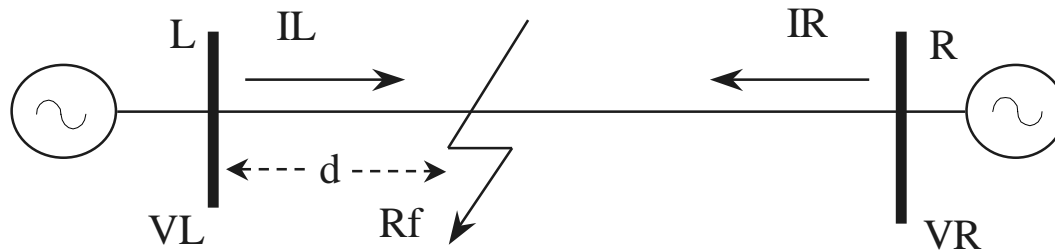


ASSUME local measured current is in phase with the total fault current
– Reactance method

$$d = \frac{\text{Im}\left(\frac{V_L}{I_L}\right)}{\text{Im}(Z)}$$



Limitations of traditional methods

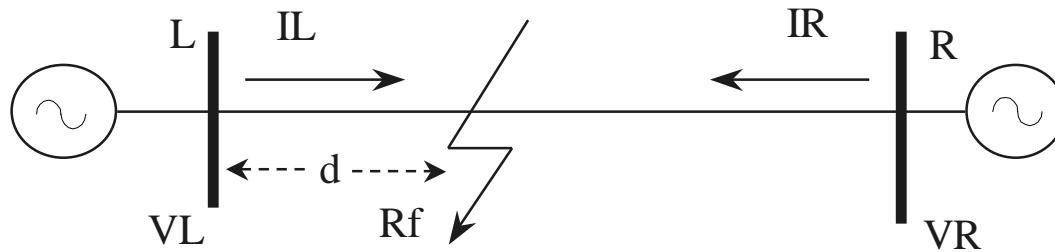


ASSUME local fault current is in phase with the total fault current
– Modified reactance method

$$d = \frac{\text{Im}(V_L I_{fL}^*)}{\text{Im}(I_L I_{fL}^* Z)}$$



Limitations of traditional methods

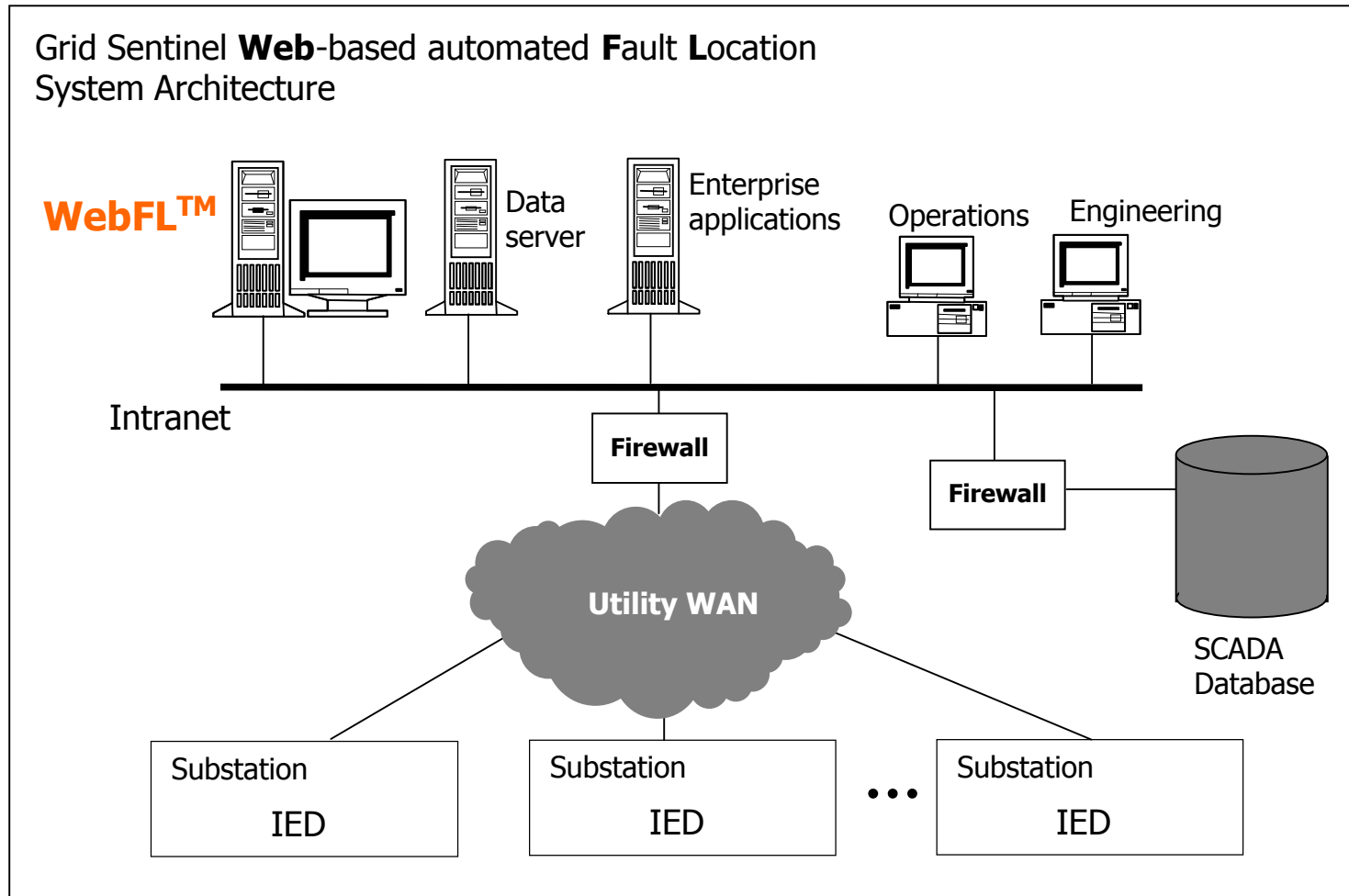


ASSUME local negative sequence current is in phase with the total fault current
-- Modified reactance method

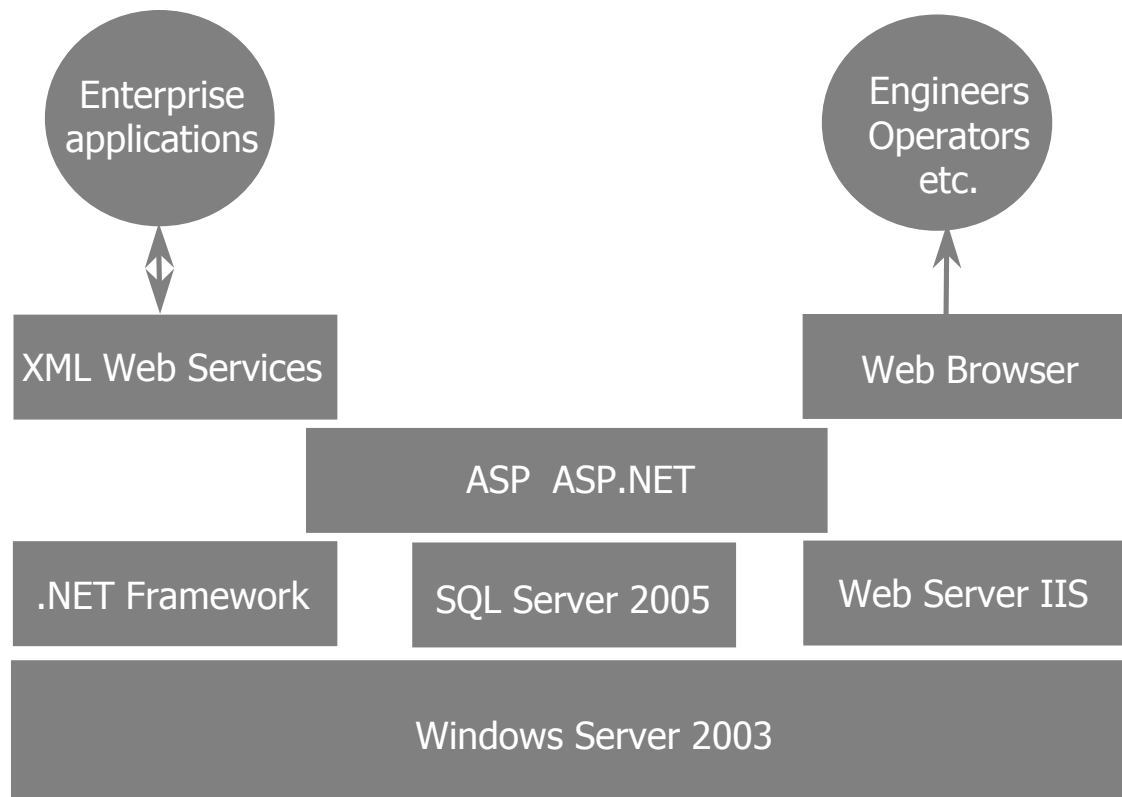
$$d = \frac{\text{Im}(V_L I_2^*)}{\text{Im}(I_L I_2^* Z)}$$



WebFL System Architecture



-
- Complete web-based solutions
 - Built with Microsoft .NET technology



-
- Innovative algorithms
 - Error less than 0.5%

Covering:

Multi-terminal lines

Two-terminal lines

Un-transposed lines

Series-compensated lines

Mutually-coupled lines

Tapped lines



Data requirements

- System data
 - Line parameters (Import from existing tools, CAPE)
 - Substation connection
 - IED (DFR, Relays) installation
- Fault or disturbance data
 - Recorded by IEDs at line terminals
 - multi-ended algorithms
 - single-ended algorithms
 - COMTRADE or proprietary



Result delivery and notification

- To system operators
 - Web interface
 - Integration to existing visualization tools (GIS or others) via XML data format
 - Email (Event-driven)
- To analysis (protection) engineers
 - Web interface
 - Email (Event-driven)



Web interface

Substations

- ⊕ S-1
- ⊕ S11
- ⊕ S-2
- ⊕ S22

WebFL [RelayStar](#)

Valid Faults [All Faults](#)

Date & Time	Fault Type	Fault Location	Substation	Line
9/17/2002 01:58:16.272	CG	9.5 (mi)	S11	line_name
1/12/1997 15:28:52.95652	AG	0 (mi)	S-1	testLine
1/12/1997 15:28:52.95652	AG	0.1 (mi)	S-2	testLine
1/12/1997 15:28:52.95652	AG	18.54 (mi)	S-1	testLine
1/12/1997 15:28:52.95652	AG	7.25 (mi)	S11	line-1

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Past 30 minutes by default



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Address <http://192.168.1.101/LineSelection.asp> Go Links

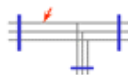
S1
[3T-line](#)

S2
[3T-line](#)

S3
[3T-line](#)

Sub 0
[line-1](#)
[line-2 untrans](#)

Sub 1
[line-1](#)
[line-2 untrans](#)



FaultLocator

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Line **line-2 untrans**; Type **Un-transposed**; Terminals [term1](#) | [term2](#)

Valid Faults [All Faults](#)

Index	Distance to term1 (mi)	Distance to term2 (mi)	Fault Type	Date & Time	Data at term1	Data at term2
<u>0</u>	49.59	50.41	AG	01/12/1997 16:32:35.67391	F2L_16.dat	F2R_16.dat
<u>1</u>	78.89	21.11	AG	02/12/1997 11:11:21.17391	F3L_16.dat	F3R_16.dat
<u>2</u>	89.78	10.22	BG	02/12/1997 11:51:39.73913	F4L_16.dat	F4R_16.dat

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Untransposed Line Fault Location

Line

- Name: [un-trans](#)
- Length: 100 miles

Phasors

Name: F3

@ Line terminals

- [Fault phasors](#)

@ Fault location

- [Phasors](#)

Fault Location	79.07 miles from s 20.93 miles from r
Fault Type	AG
Fault Resistance	Rag = 3.36 Ohms
r Delaying	20.23 degrees

Internet

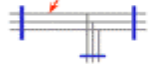


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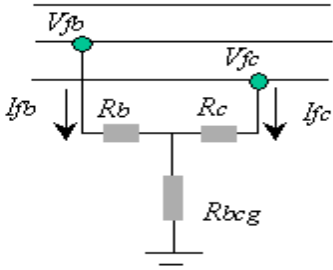


Three-terminal Line Fault Location

Data: R_bcg_80m_500

Line Name	S	R	T	S -- Tap	R -- Tap	T -- Tap
<u>three</u>	s	r	t	100 miles	100 miles	40 miles

Fault Location	Fault Type	Fault Resistance
80.01 miles (from r)	BCG	Rb = 51.26 Ohms Rc = 48.12 Ohms Rbcg = 0.37 Ohms



Internet

XML report

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
- <faults>
  <date>05/28/2006</date>
  <time>16:55:49</time>
  <data>Yes</data>
- <fault>
  <date>11/26/2005</date>
  <time>04:21:01.120000</time>
  <feeder_name>line-1</feeder_name>
  <fault_location>15.35</fault_location>
  <from_sub>sub1</from_sub>
  <fault_type>AG</fault_type>
</fault>
</faults>
```

Report time

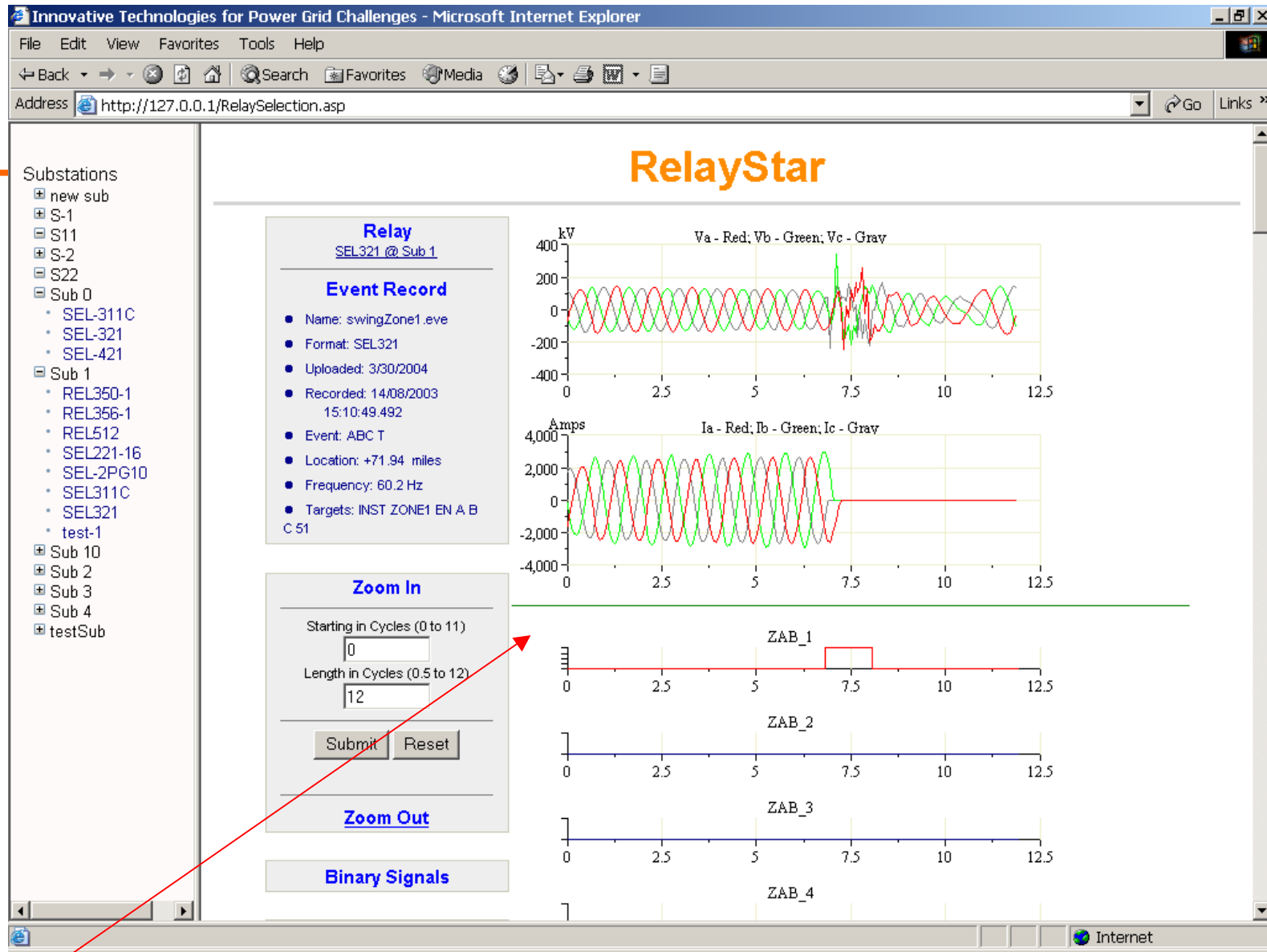
Fault information



Relay simulator

- Overcurrent
- Voltage
- Directional – phase & ground
- Distance – phase & ground
- Current differential
- Phase comparison





Oscillographic display

Web Record Analyzer - Microsoft Internet Explorer

Address http://127.0.0.1/relayexpert_phasors.asp?data_format=SEL321

Phasor Diagrams

Relay
SEL321 @ Sub 1

Event Record

- Name: swingZone1.eve
- Format: SEL321
- Uploaded: 3/30/2004
- Recorded: 14/08/2003 15:10:49.492
- Event: ABC T
- Location: +71.94 miles
- Frequency: 60.2 Hz
- Targets: INST_ZONE1 EN A B C 51

<input checked="" type="checkbox"/> Va = 94.15@0.00	<input checked="" type="checkbox"/> Vb = 87.76@240.59	<input type="checkbox"/> Vc = 92.48@124.64
<input checked="" type="checkbox"/> V0 = 0.52@-166.32	<input type="checkbox"/> V1 = 91.40@1.75	<input type="checkbox"/> V2 = 4.24@-39.05
<input type="checkbox"/> Ia = 1561.95@-22.52	<input checked="" type="checkbox"/> Ib = 1712.02@213.67	<input checked="" type="checkbox"/> Ic = 1554.65@89.94
<input type="checkbox"/> I0 = 6.95@19.41	<input type="checkbox"/> I1 = 1607.27@-26.29	<input type="checkbox"/> I2 = 111.47@92.42

Ref: Va

Cycle: 1.0
 ◀ ▶

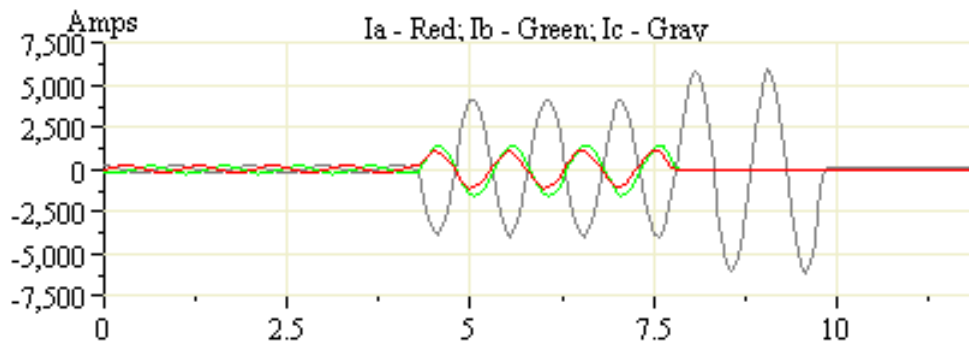
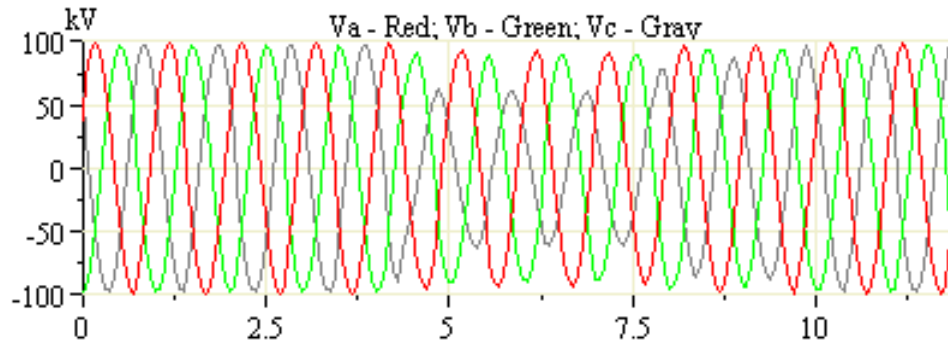
Sample: 16 (16.7 ms)

V Scale: 1
 ◀ ▶

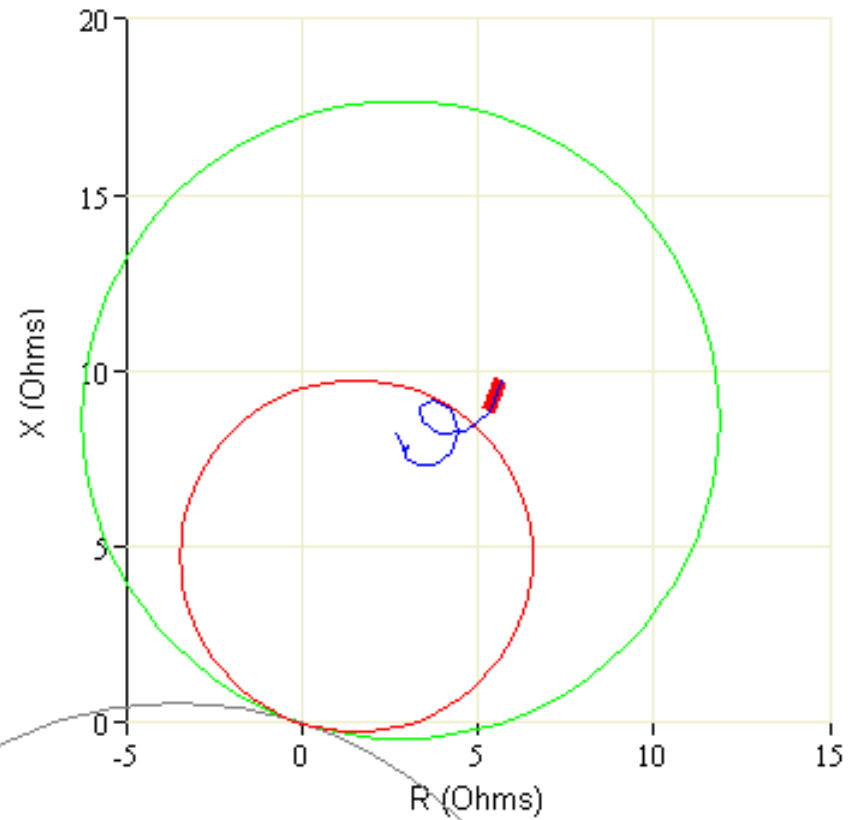
I Scale: 1
 ◀ ▶

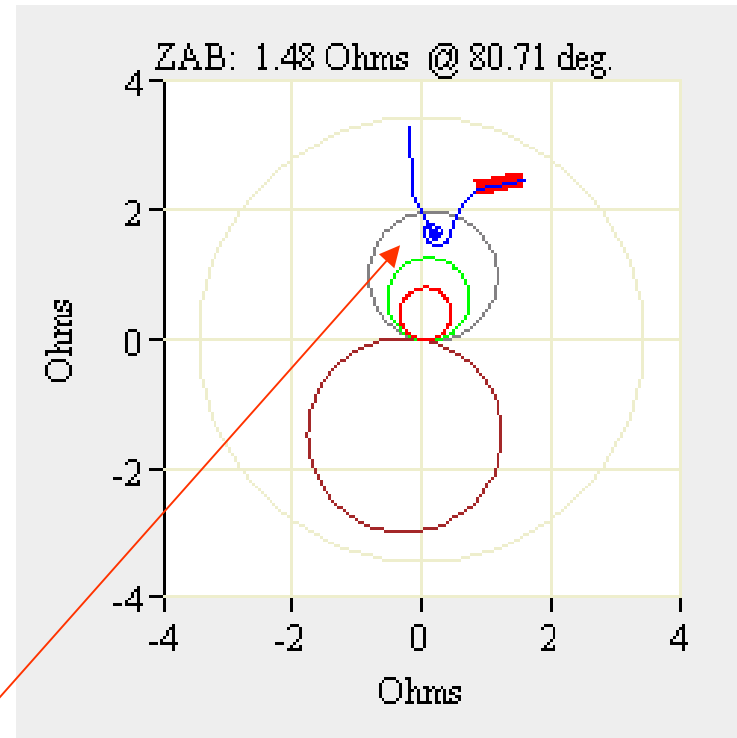
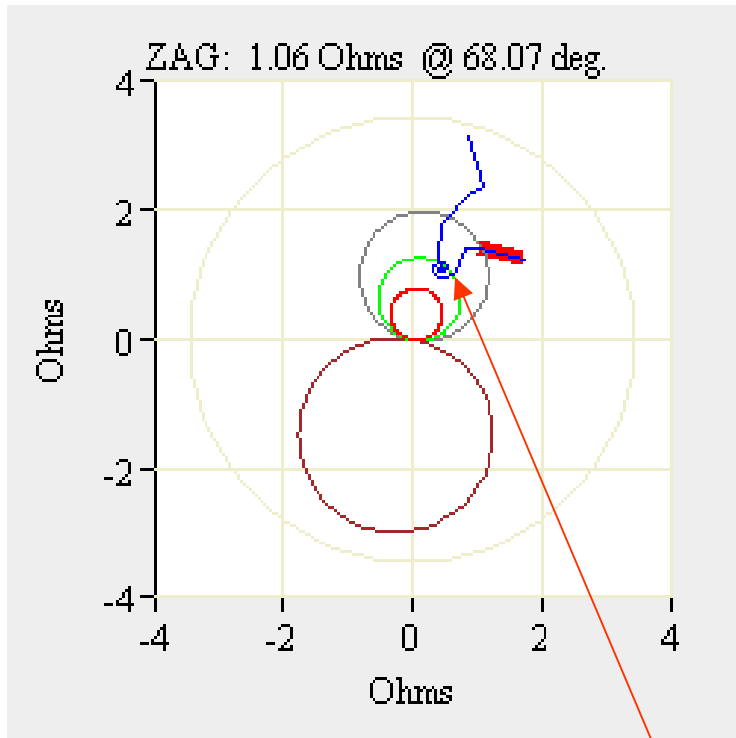
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Applet rePhasorData started Internet



Time (C): 8 to 10; ZCG: 8.01 Ohms @ 65.82 deg.





Ground distance element overreaches for a line-line-to-ground fault



Automated event diagnosis

Sub 0
[SEL-311C](#)
[SEL-321](#)
[SEL-421](#)

Sub 1
[REL350-1](#)
[REL356-1](#)
[REL512](#)
[SEL-121F](#)
[SEL-121G](#)
[SEL221-16](#)
[SEL-2PG10](#)
[SEL-311B](#)
[SEL311C](#)
[SEL321](#)
[SEL-421](#)

Sub 2
[DFR-1](#)
[REL350-2](#)
[REL356-2](#)

Sub 3
[REL352](#)

Sub 4
[MDAR-1](#)
[MDAR-2](#)

Data Files

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Settings: [System](#) | [Fault Location](#) | [Overcurrent](#) | [Voltage](#) | [Distance](#) | [OOS](#)
[Polar Diagram](#)

Relay SEL321 @ Substation Sub 1

Index	Data	Diagnosis	Format	Date Uploaded
0	sel321.eve	Breaker fails to trip (I.F)	SEL321	2/9/2004 5:30:59 PM
1	swingZone1.eve	Relay slow trip	SEL321	3/30/2004 7:23:45 PM

Total File Size: 44 KB; Limit: 5000 KB

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Address http://192.168.1.101/relayexpert/diagnosisReport.asp?file_index=1023 Go Links



Event Diagnosis Report

Diagnosis result	Relay false trip; Breaker fails to trip (E.F.)
Event site	Station name: Sub 0 Line name: Line-2 Line length: 12.04 miles Relay name: SEL-321 Breaker name: Breaker-2
Fault property	Fault type: CG Fault location: +13.50 miles Fault date: 05/12/04 Fault time: 71.88 ms (21:03:10.892) Fault duration: * Data: SEL-321-Event.eve
Relay and breaker operations	Relay trip time: 134.38 ms (21:03:10.892) Breaker trip time: *

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Done Internet



WebFL™ key benefits

- **Saves money** by helping system operators achieve fast and correct service restorations with real-time fault location – Decision support tool
- **Saves** protection engineers **time** through automated fault diagnosis and relay performance evaluation – Productivity improvement solution
- Readily extensible to distribution circuits improving **SAIDI** and **SAIFI**



Questions?

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