Prepared By Theo Laughner (TVA), PE

Acknowledgements –

Fred Elmendorf (GPA), Bill Howe (EPRI), Ralph McKoskey (TVA), Bruce Rogers (TVA)

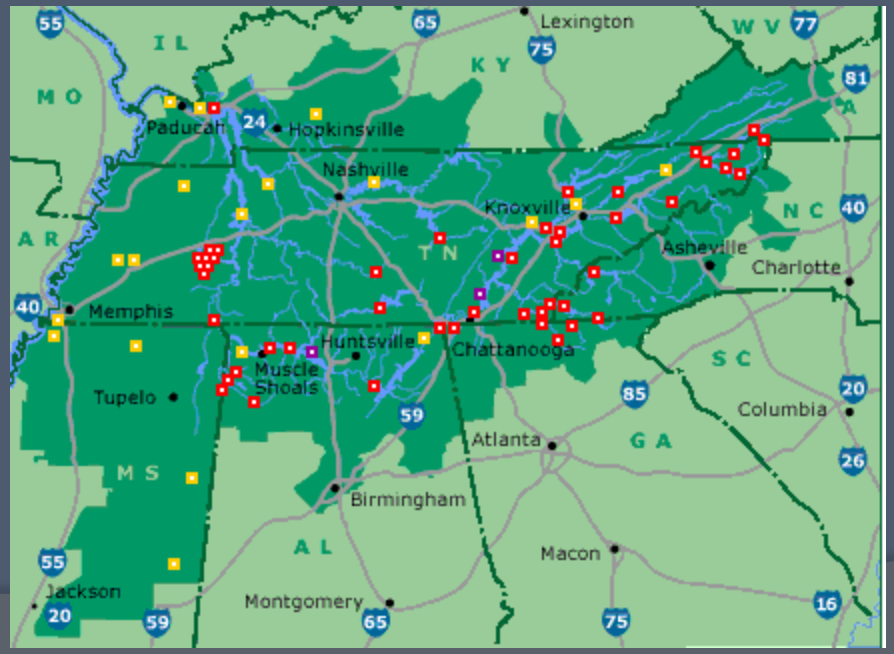
TVA AUTOMATED FAULT LOCATION

Outline

- About TVA
- Motivation for Automating Fault Location
- Industry Fault Location Projects
- EPRI Fault Location Projects
- Current State of Fault Location at TVA
- Future State of Fault Location at TVA

About TVA


Corporate Snapshot
Name: Tennessee Valley Authority
Industry: Utilities
Sales Revenues: $11.7 billion
Power Sales: 167 billion kwh
Financing: Receives no appropriated tax dollars
Employees: 12,000
Taxes: Paid nearly $530 million in tax equivalent payments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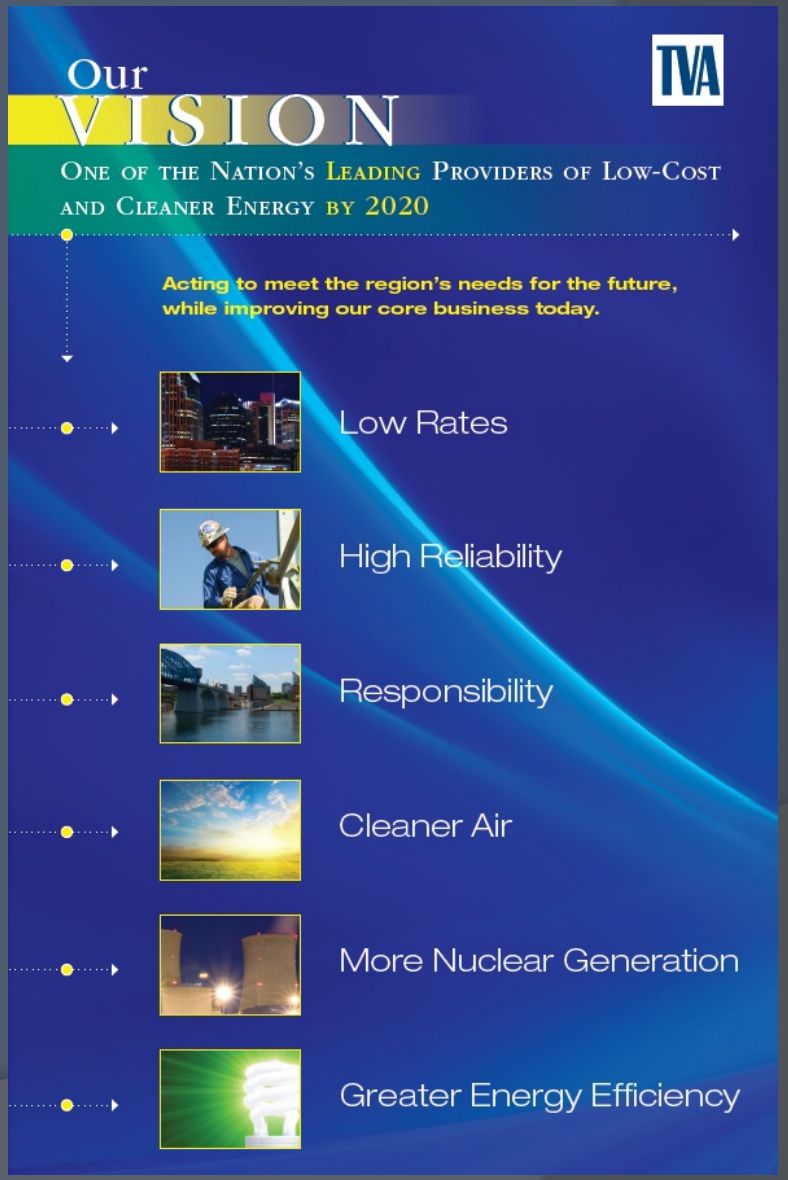

Our VISION
TVA
One of the Nation's Leading Providers of Low-Cost and Cleaner Energy by 2020
Acting to meet the region's needs for the future, while improving our core business today.
Low Rates
High Reliability
Responsibility
Cleaner Air
More Nuclear Generation
Greater Energy Efficiency

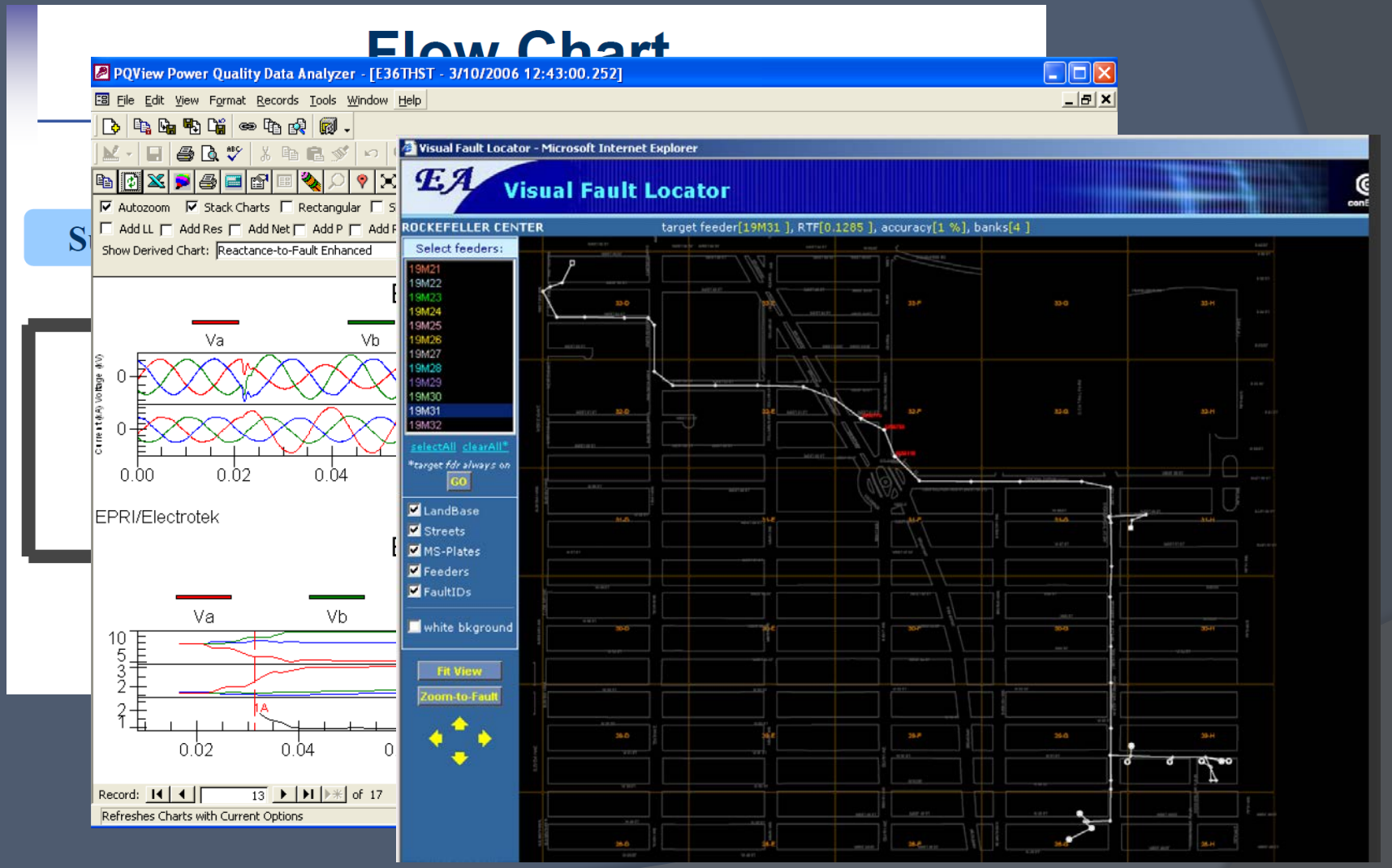
Motivation for Automating Fault Location

- Higher Customer Satisfaction
- Improved Reliability
- Reduced Time to Repair Failure
  - Dispatching field resources more quickly, accurately

Automated Utility Fault Location Projects

- Con Ed
- Detroit Edison
- San Diego Gas & Electric

Con Ed



Source: PQA / ADA 2006 – Fault Location for Underground Systems – Paul Stergiou, Da

Detroit Edison

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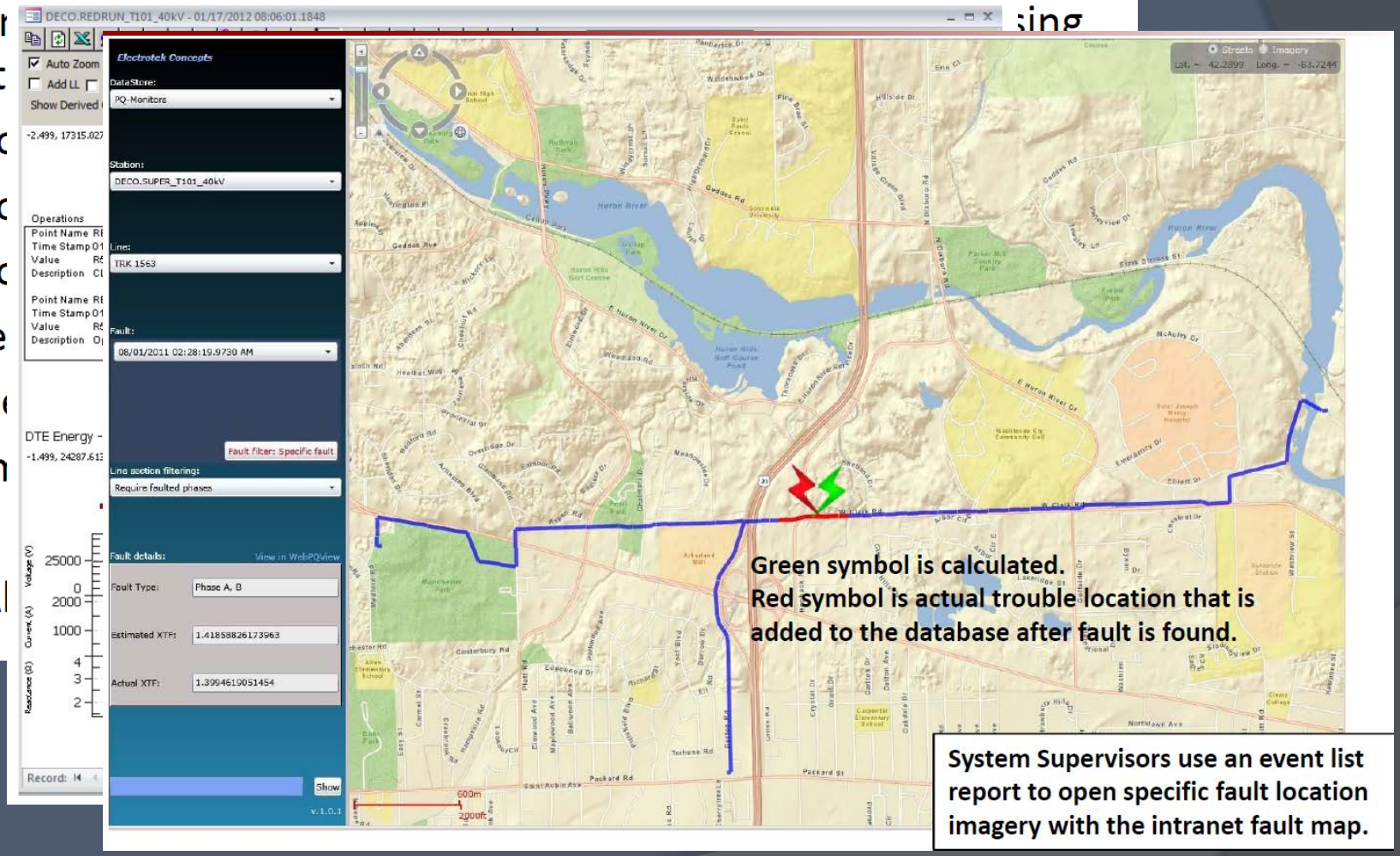
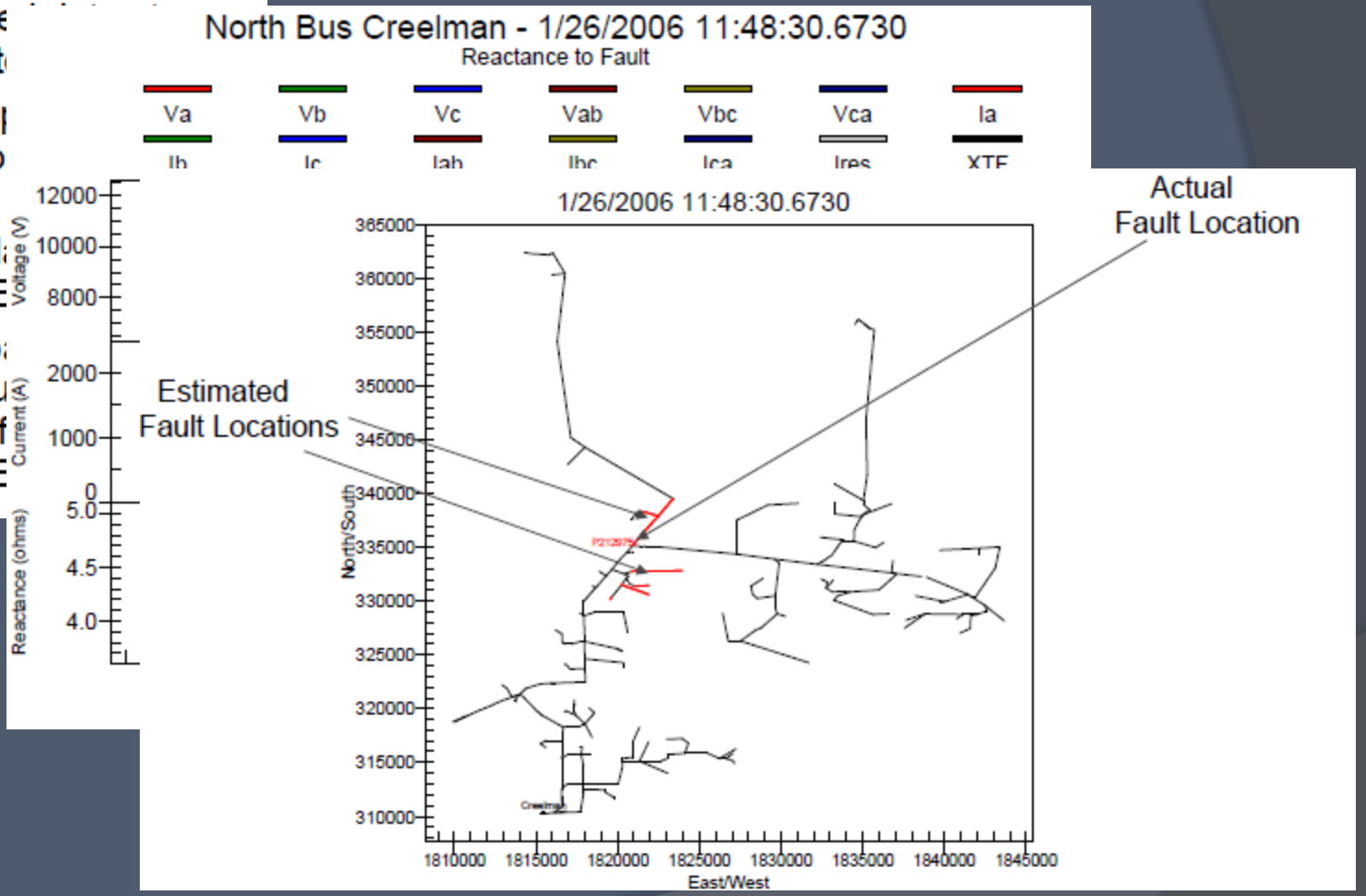


Source: Overview of Automatic Subtransmission Fault Location System at DTE Energy – Andrew Dettloff, Dan Sabin

SDG & E

Mechanics

- Use monitore
  substations t
- Calculate imp
  using monito
  View
- Match calcul
  to SynerGEE
- Display probe
  on one-line u
  coordinates f
  of SynerGEE



Source: Integrated Monitoring Distribution Fault Analysis with Spatial Twist - Joe Frani/Dar

PRI Fault Location: The OpenFLE" initiative

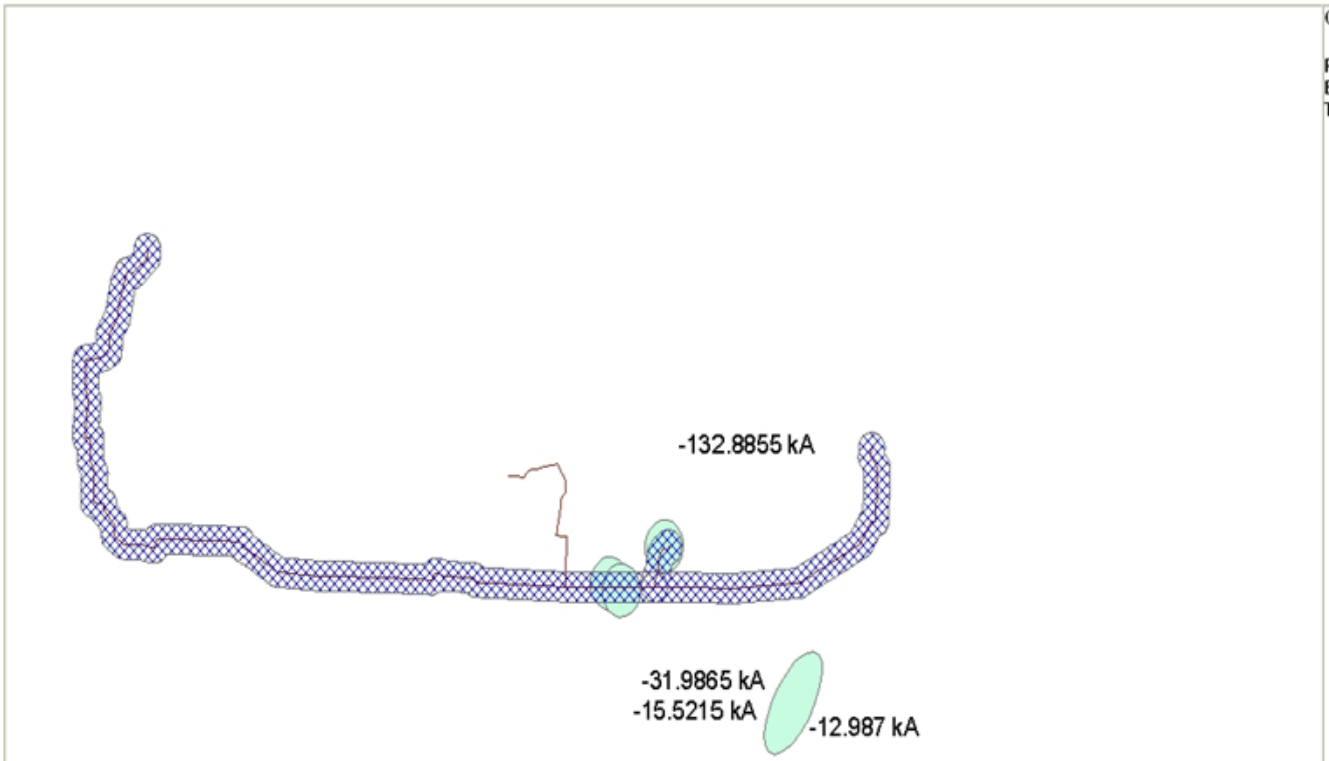
- Create a common gathering place for data interface capability (Input)
- Create a common gathering place for algorithms and knowledge related to calculating fault location (Processing)
- Create a common gathering place for user interface (Output)
- Platform independent
- Multiple providers and applications

EPRI Fault Location Research Projects

- Capacitor Bank Failure
- Transformer Health Assessment
- Distribution Fault Anticipator
- Lightning

TVA Automated Fault Location Efforts

Event Date: 09/06/2009 11:17:51 PM



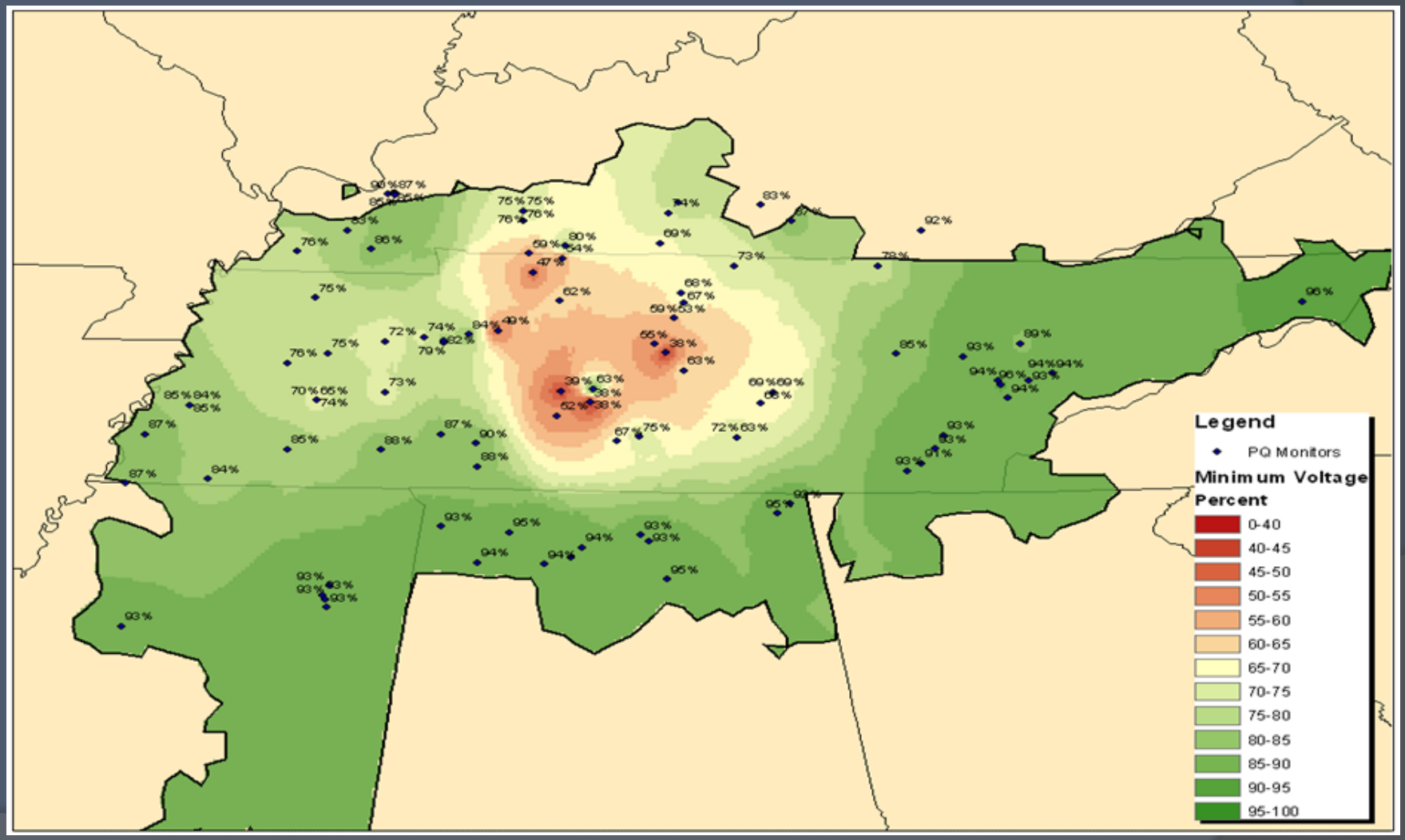
Query Parmameters

Points of interest: 6079,5432,L5934
Buffer Size (ft): 1640
Time Window (s): 2

Event Time	Peak kA	Latitude	Longitude
09/06/2009 11:17:49 PM	-15.5215	34.90445	-89.84736
09/06/2009 11:17:49 PM	-31.9865	34.90257	-89.84213
09/06/2009 11:17:49 PM	-132.8855	34.91631	-89.82483
09/06/2009 11:17:49 PM	-132.8855	34.91631	-89.82483

Found: 4

TVA Automated Fault Analysis Efforts



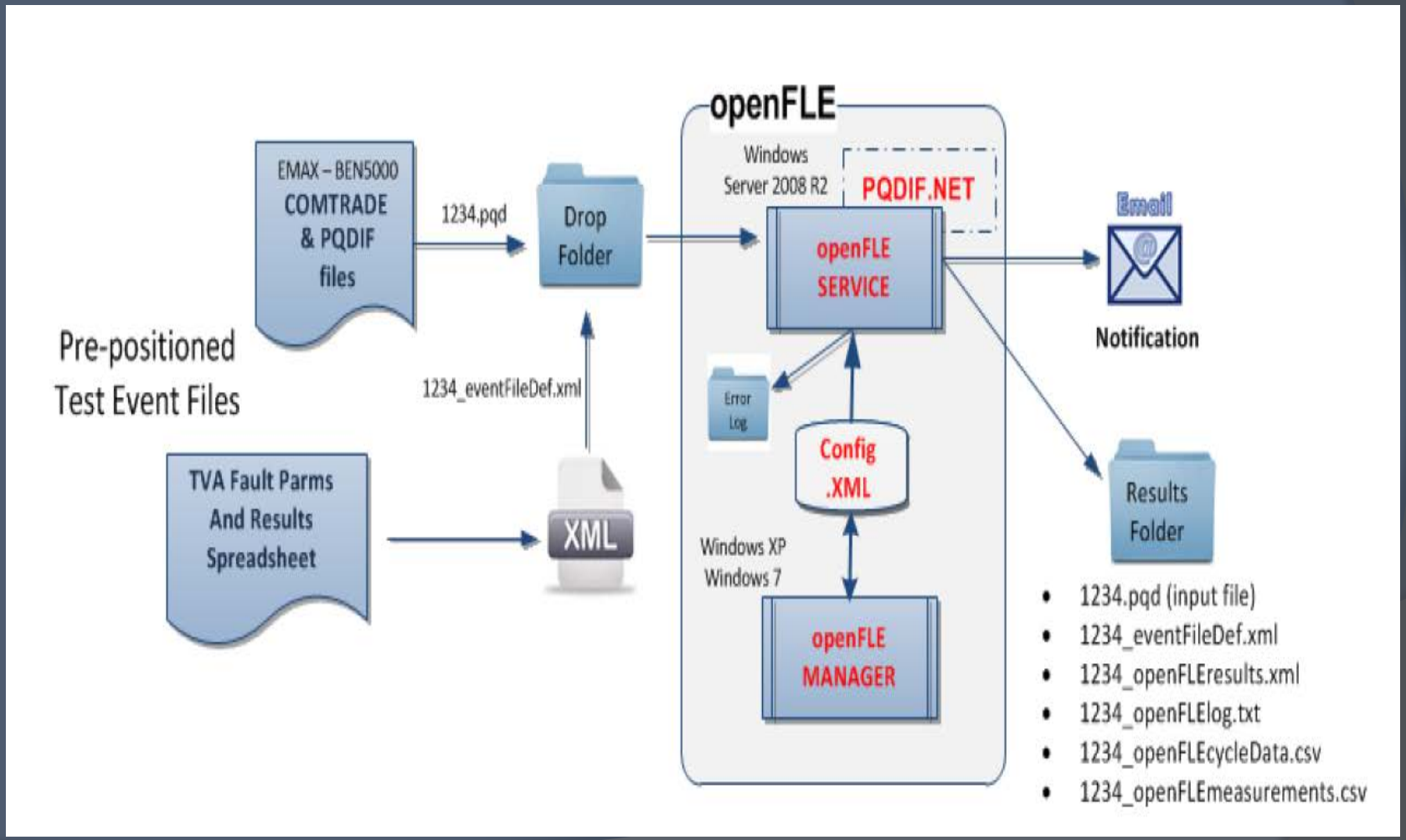
Punchline

- There is not a single fault location algorithm, there are many!
- There is not one source of data, but many!
- There are many system modeling software packages!

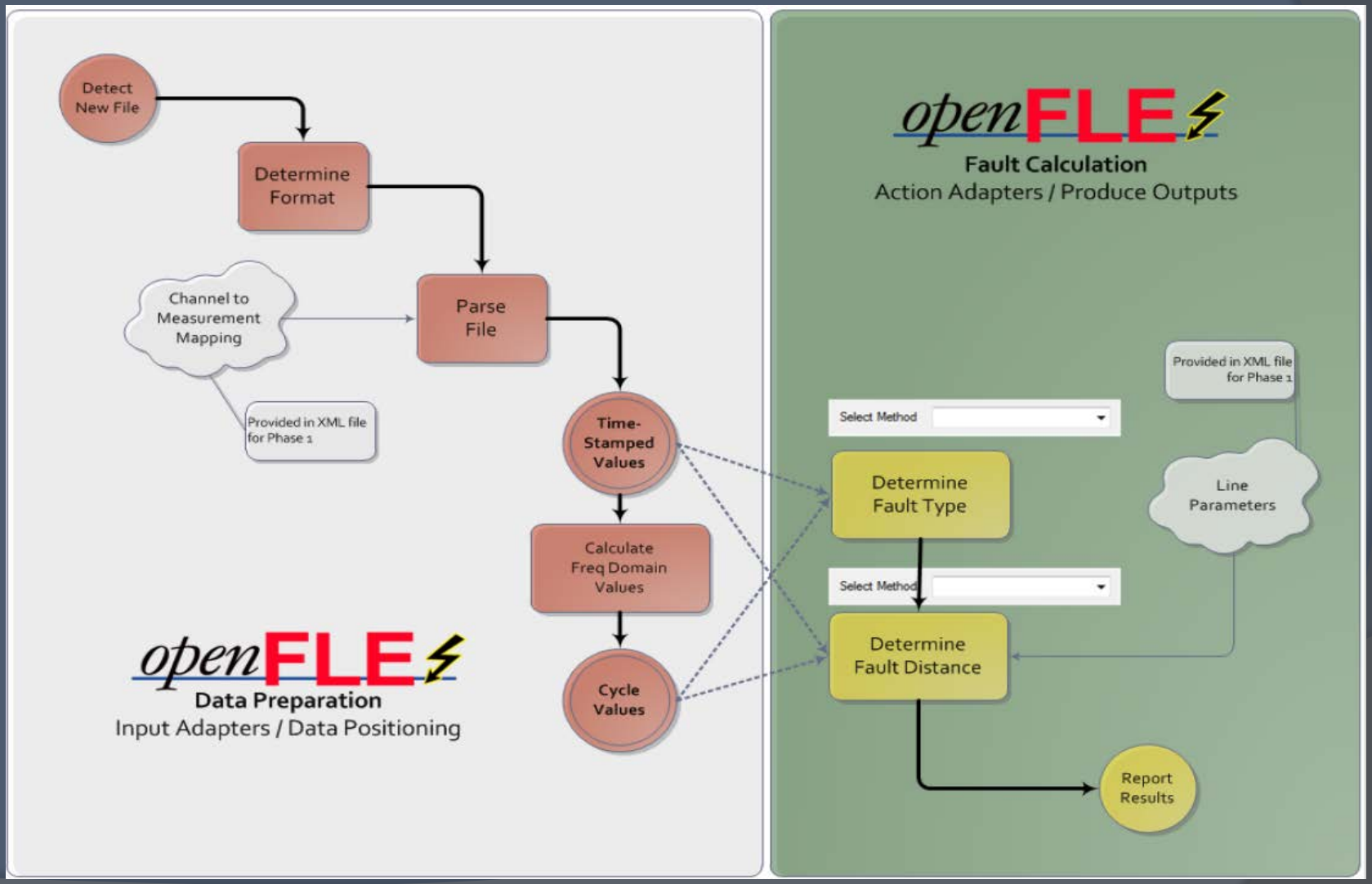
Open Fault Location Engine (openFLE)

- Platform
  - Get Event Data
    - Frees developers from the chore of reliably parsing and positioning event data for analysis
  - Perform Calculations
    - Can be extended with new algorithms

Open Fault Location Engine (openFLE)



Approach


Detect New File
Determine Format
Channel to Measurement Mapping
Parse File
Provided in XML file for Phase 1
Time-Stamped Values
Calculate Freq Domain Values
Cycle Values
openFLE
Data Preparation
Input Adapters / Data Positioning
openFLE
Fault Calculation
Action Adapters / Produce Outputs
Provided in XML file for Phase 1
Select Method
Determine Fault Type
Line Parameters
Select Method
Determine Fault Distance
Report Results

Fault Detection

- Assume the first cycle represents pre-fault condition
- A fault is detected in any cycle where the RMS current (cycle value) exceeds pre-fault current by a factor of 5 AND exceeds 500 amps Improvement: Use line ratings as part of the basis for fault detection.

Fault Type

- For each phase, the fault test was applied
- The representative best fault cycle is selected as the one with the largest sum of all RMS currents
- The number of currents which pass the fault test determine the fault type.

Fault Location

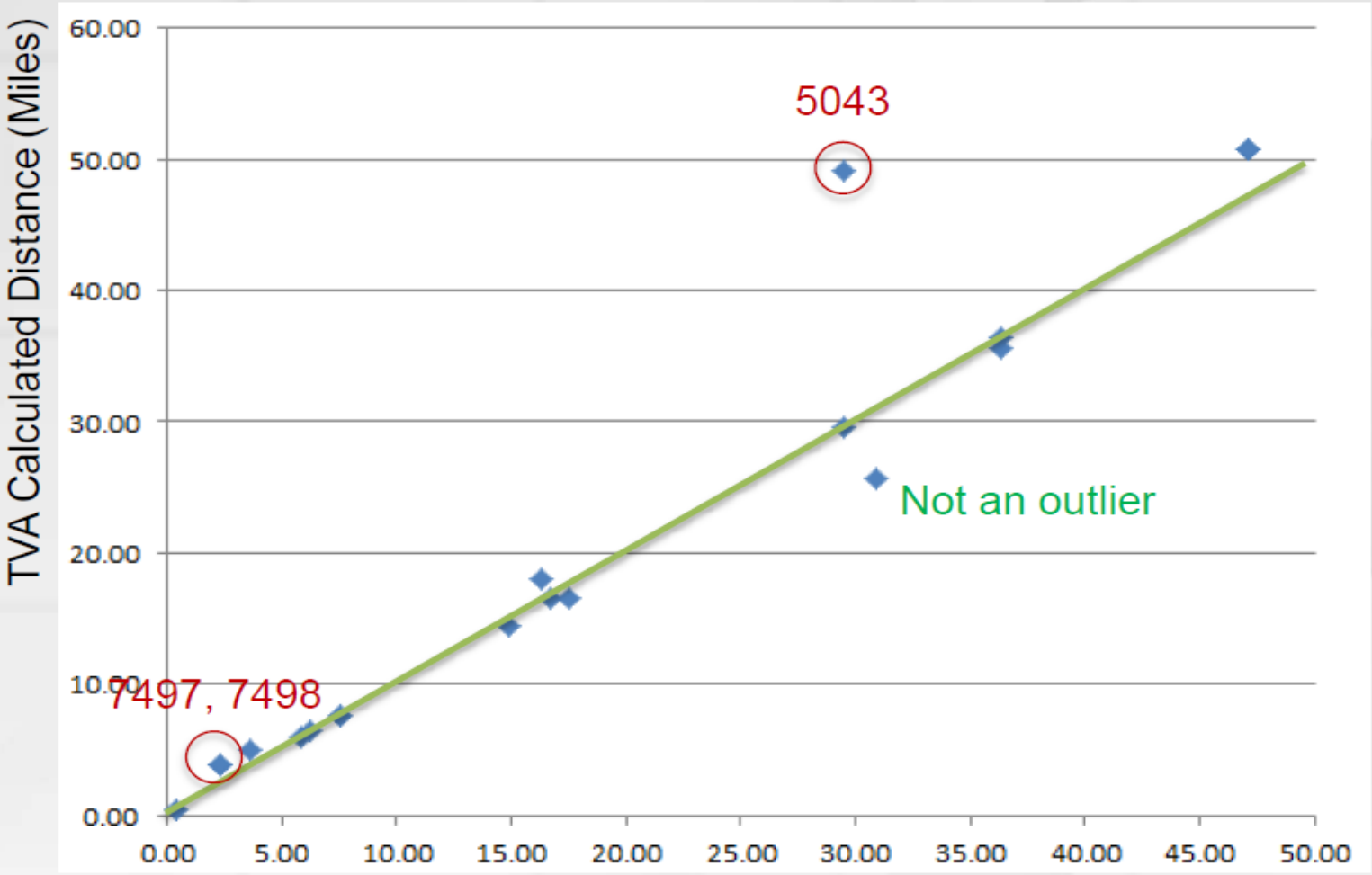
- Calculated Fault Impedance using the Absolute Value Method (Reactance method was tested and found to be less accurate.)
- 3 Phase
  - Select phase with “purest” sine wave
  - ZF = RMS (cycle data) |VN| / |I|
  - Distance is ratio ZF/Z1
- Line to Ground
  - ZF = RMS (cycle data) |VN| / |I|
  - Distance is ratio ZF/ZS (where ZS is loop impedance)
- Line to Line
  - ZF = RMS (cycle data) |VL-L| / (|IP1 - IP2|)
  - Distance is ratio ZF/Z1

System Results

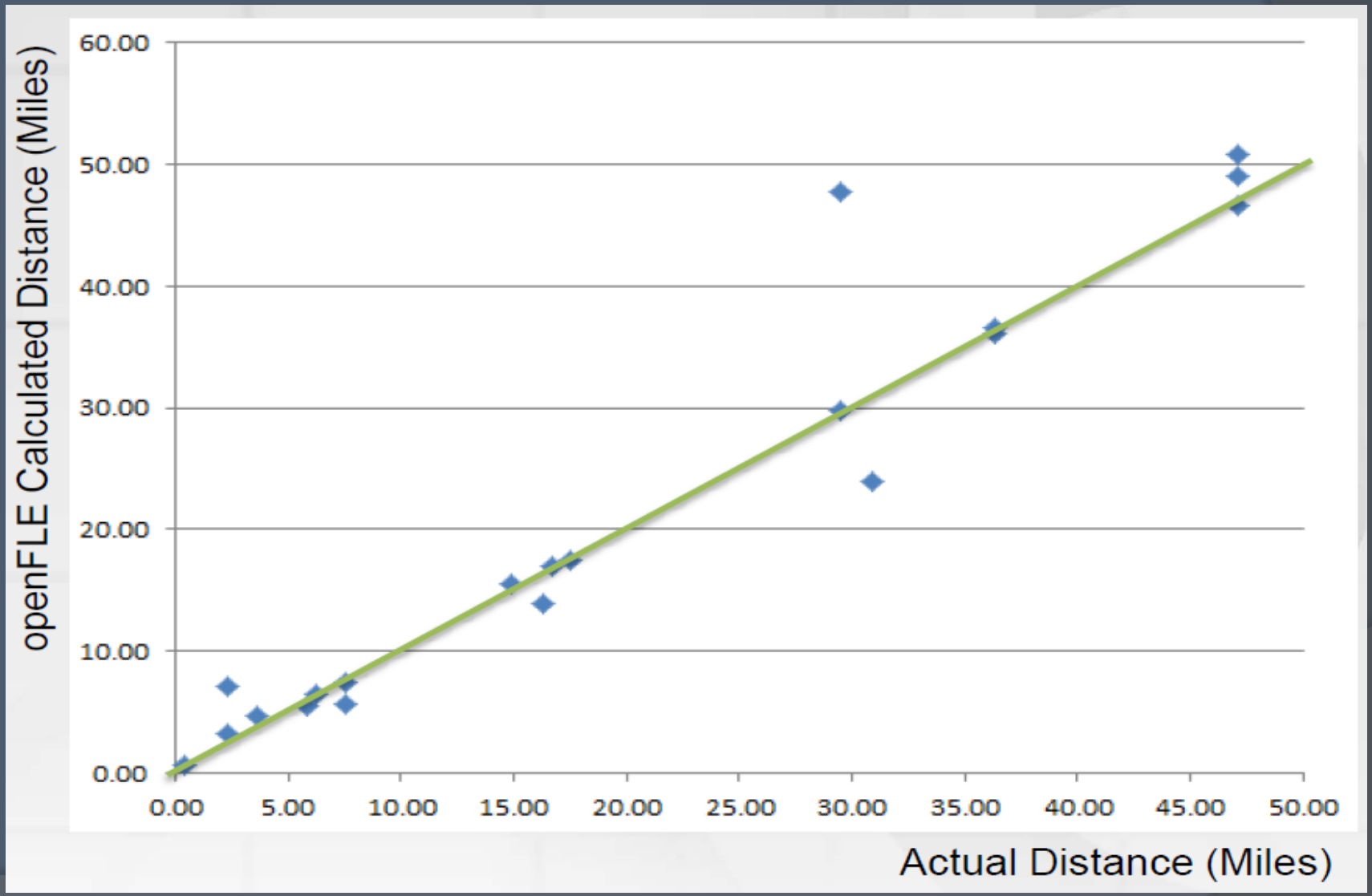
			TVA		openFLE	
Record #	Fault Type	Line Distance	Calculated	Actual	Absolute	Reactance
1337	BC	12.58	7.60	7.54	5.65	5.37
1337	BC	12.58	7.60	7.54	7.50	7.18
1586	A	21.15	6.40	6.25	6.53	6.38
5041	ABC	83.45	35.60	36.36	36.62	36.69
5043	ABG	46.25	49.10	29.49	47.68	46.58
5346	ABC	23.39	5.90	5.86	5.48	5.55
7497	AB	18.63	3.90	2.34	3.29	3.31
7498	AB	18.63	3.90	2.34	7.10	6.21
7550	A	21.15	14.40	14.90	15.57	15.43
7707	AB	18.63	18.00	16.29	13.90	13.84
8403328	ABC	83.45	36.40	36.36	36.13	36.23
8747364	ABG	46.25	29.60	29.49	29.80	29.22
1022	ABC	83.45	50.70	47.09	50.79	50.78
1023	ABC	83.45	50.70	47.09	49.01	45.28
1024	ABC	83.45	50.70	47.09	46.67	44.42
1053	ABG	46.25	16.60	16.76	17.03	16.50
1056	ABC	4.67	5.00	3.61	4.76	4.78
1060	A	31.30	0.50	0.44	0.65	0.49
1085	A	31.30	25.70	30.86	23.99	23.75
1537	ABC	23.39	16.60	17.53	17.46	-16.50

Manual Vs. Actual

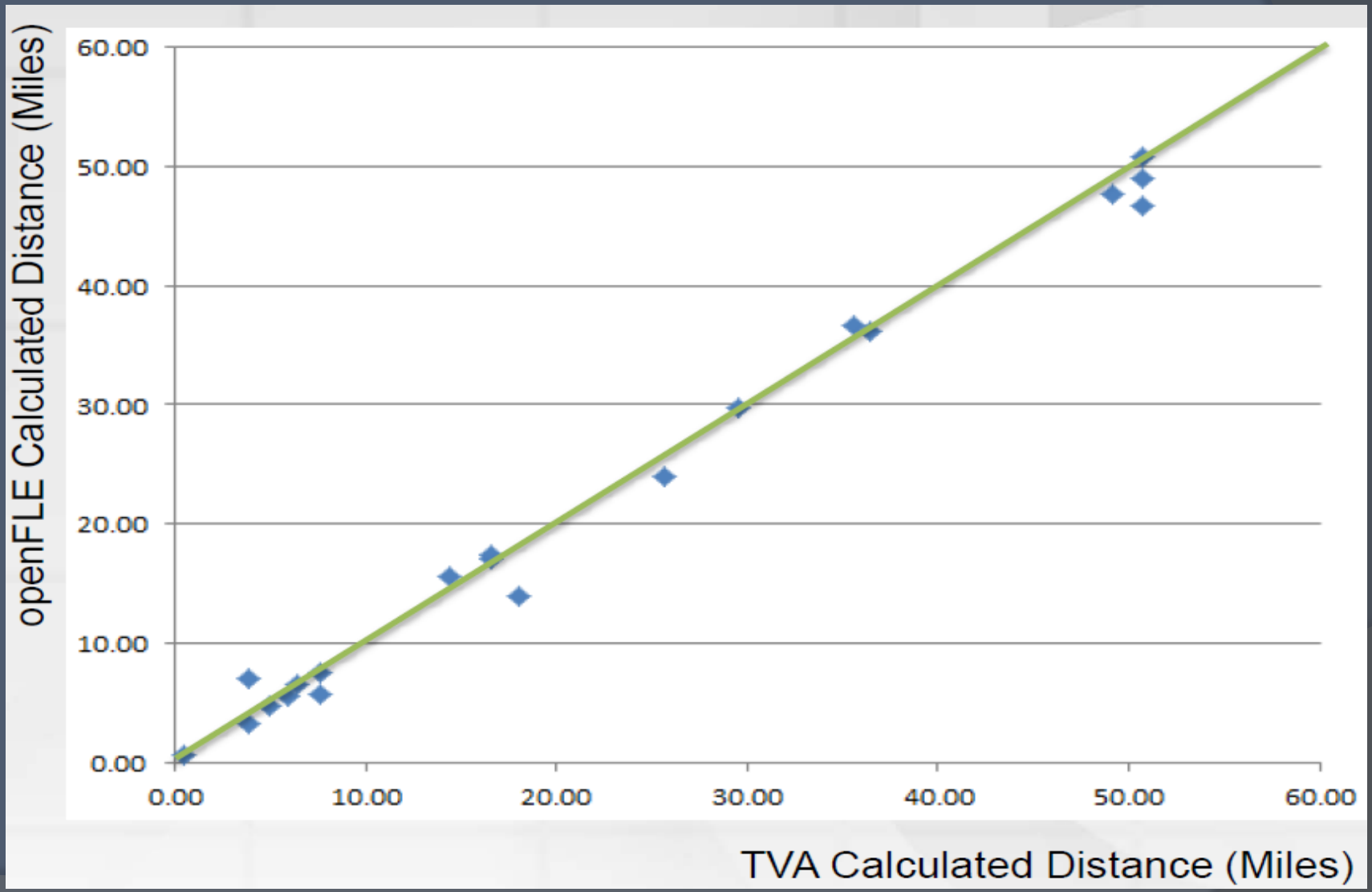
3 outliers where TVA calculation error is greater than 50%



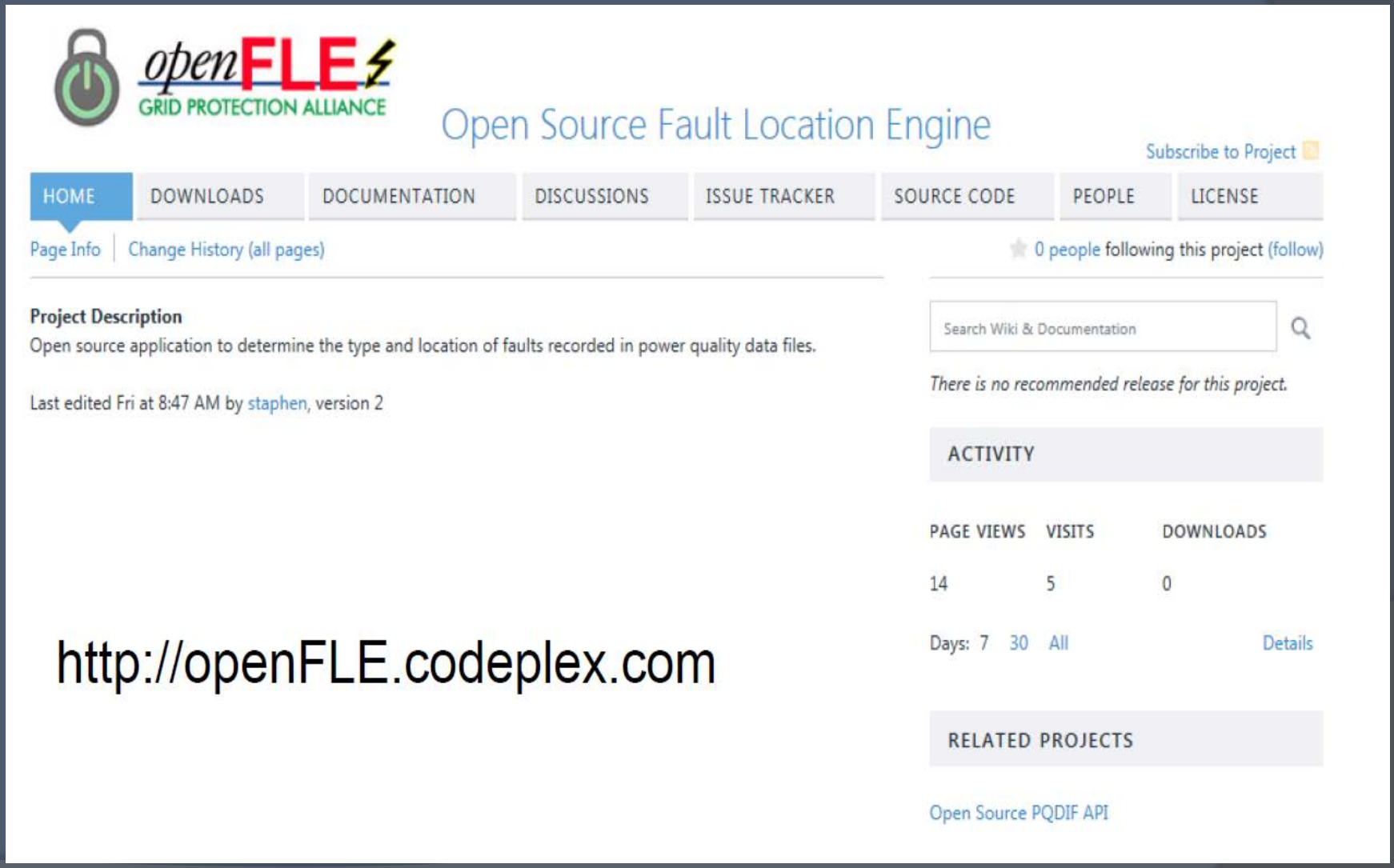
openFLE vs. Actual



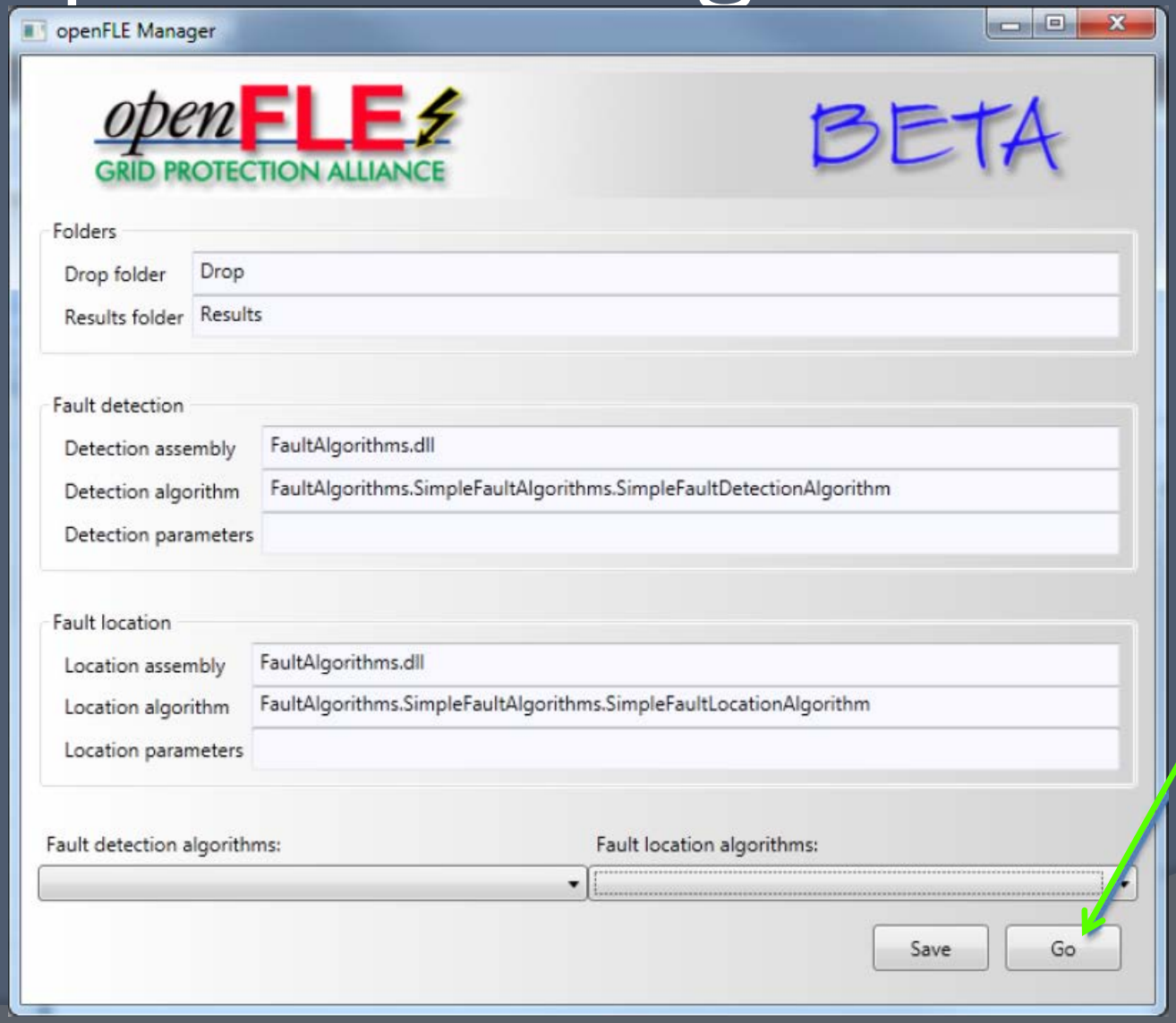
openFLE vs. Manual



openFLE CodePlex Template



openFLE Manager



Button to facilitate testing

Project Status

- Testing was conducted on 161kV line events
- TVA provided GPA with 8 events for testing – some with data from each end of the line
- GPA has finished development and testing of the core software.
- GPA Next Steps
  - Complete requirements document and submit BETA for EPRI QA testing
  - Post code and documentation on CodePlex
- Future work can be pursed to:
  - Automate the process within TVA
  - Refine and improve fault location algorithms

Conclusion

- Platform Built
  - openPQDIF API Built
    - (http://openpqdif.codeplex.com)
  - openFLE
    - (http://openfle.codeplex.com)
- Initial Testing Performed
  - Accurate
  - Fast
- To be completed
  - TVA System Integration