A TECHNIQUE FOR DETECTING WIDE-AREA SINGLE-LINE-TO-GROUND FAULTS

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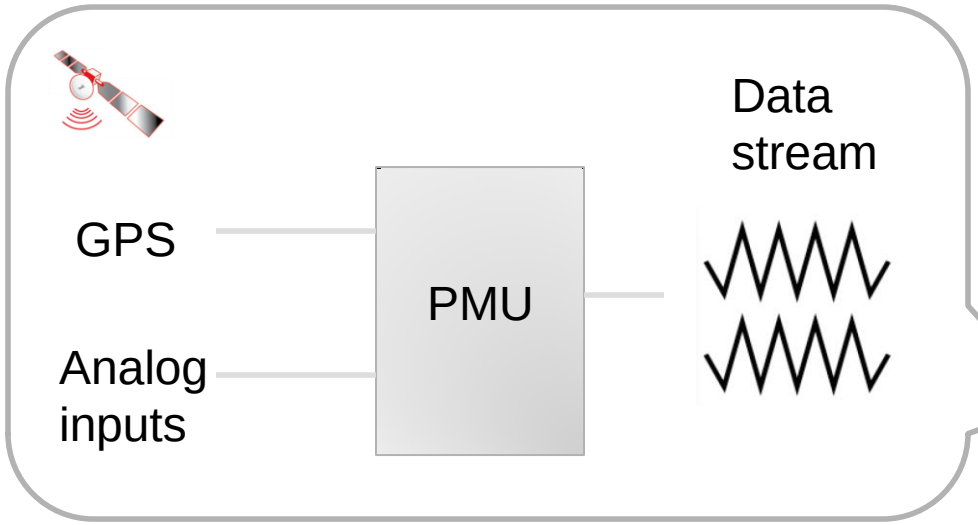
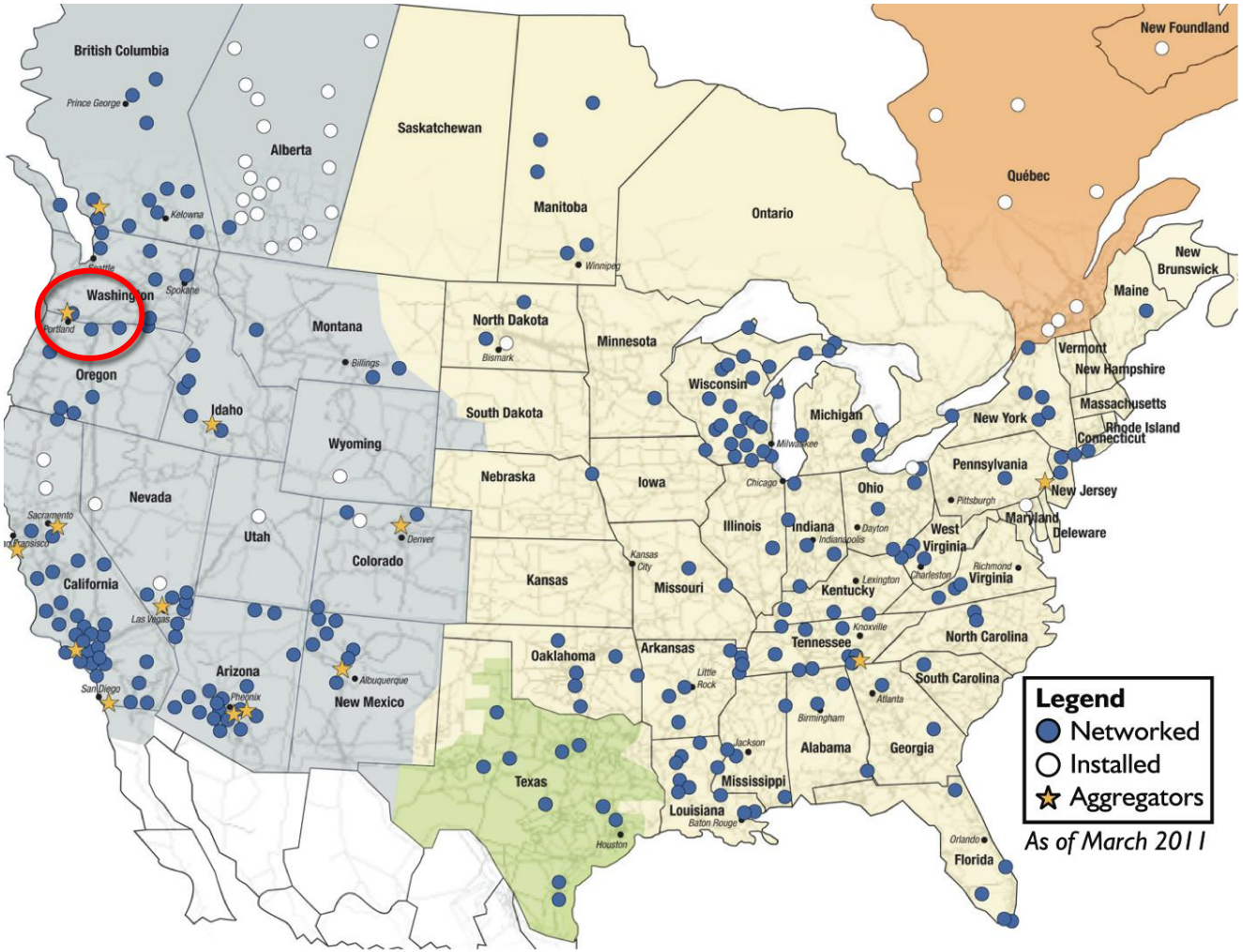
Wide-Area Measurement System

- Wide-Area Measurement System (WAMS) utilizes Phasor Measurement Unit (PMU) to monitor real-time power system data
- This technology offers great potential for the development of smart power transmission systems

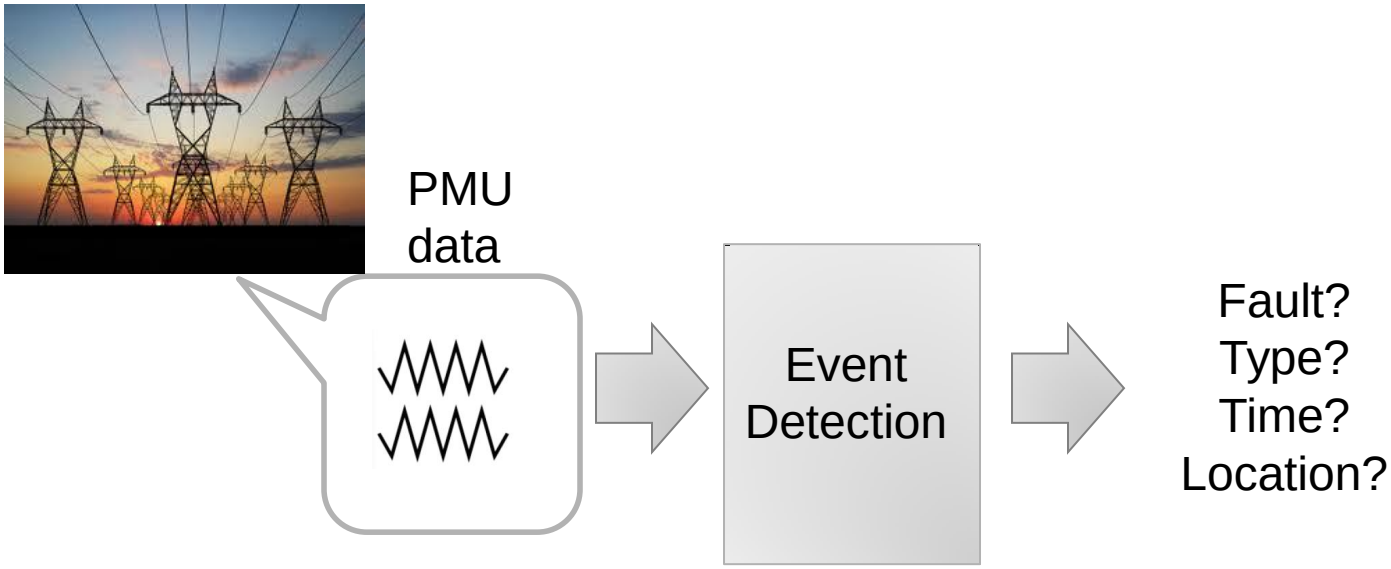




Source: North American SynchroPhasor Initiative, as of March 8, 2012.
Note: Regional PMU data are centralized and archived at aggregators (see stars on map).

Objective

- Develop a fault detection method using PMU data for wide area power grid

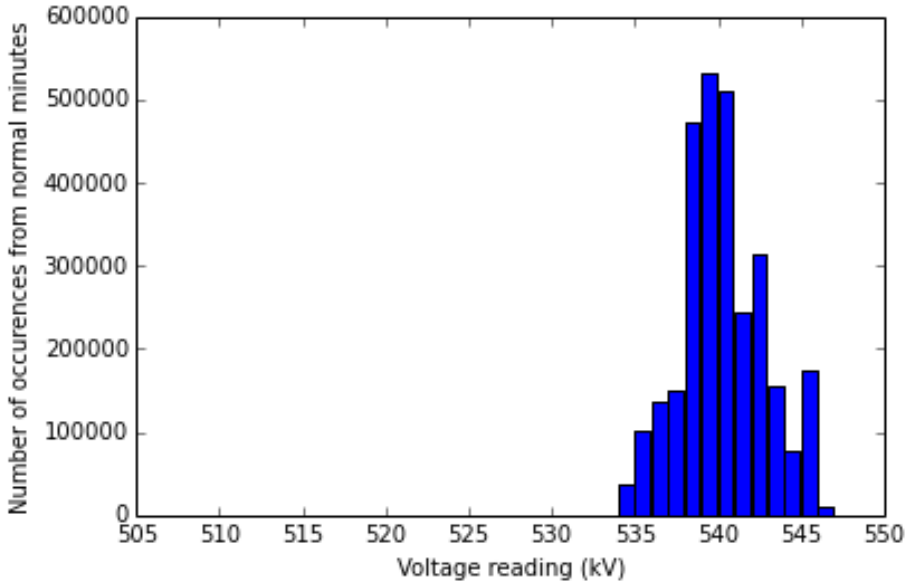


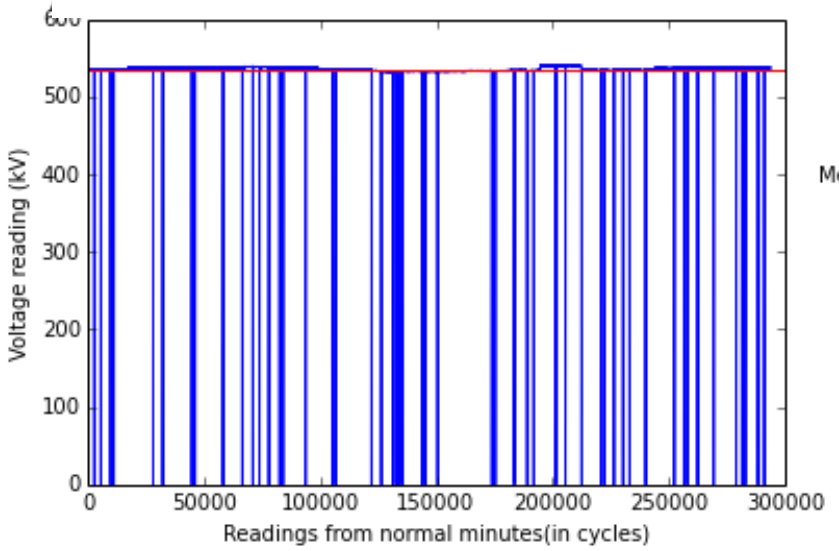
Dataset

- PMU dataset
  - Three phase and positive sequence voltage phasors for buses
  - Positive sequence current phasors for lines
  - Site frequency
  - 31 sites; >1200 signals; ~15Mb/min
- Fault annotations
  - 120 faults on lines with PMUs at one or more ends
  - Annotated with field & dispatch notes
  - Between 10/17/2012 – 9/6/2013

Data Characterization

Tight clustering of normal voltage signal around nominal bus value

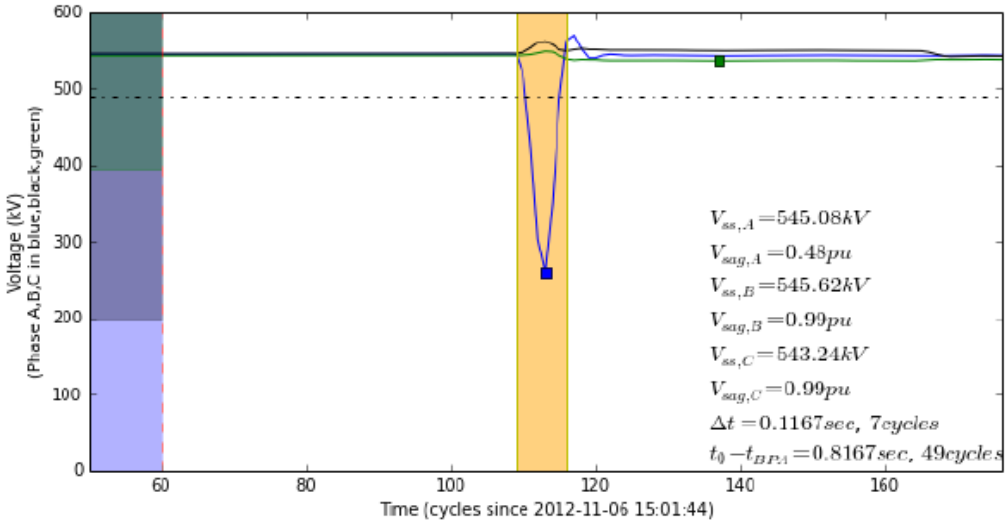


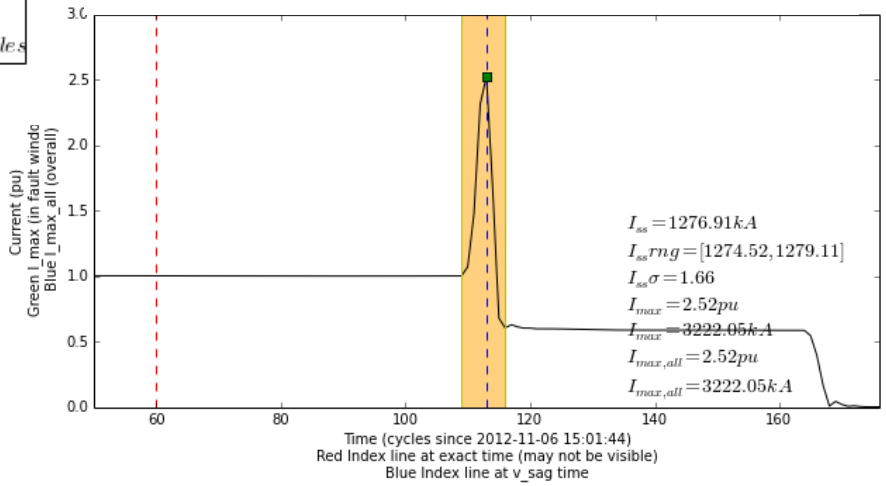


Mean Voltage = 535.527044071

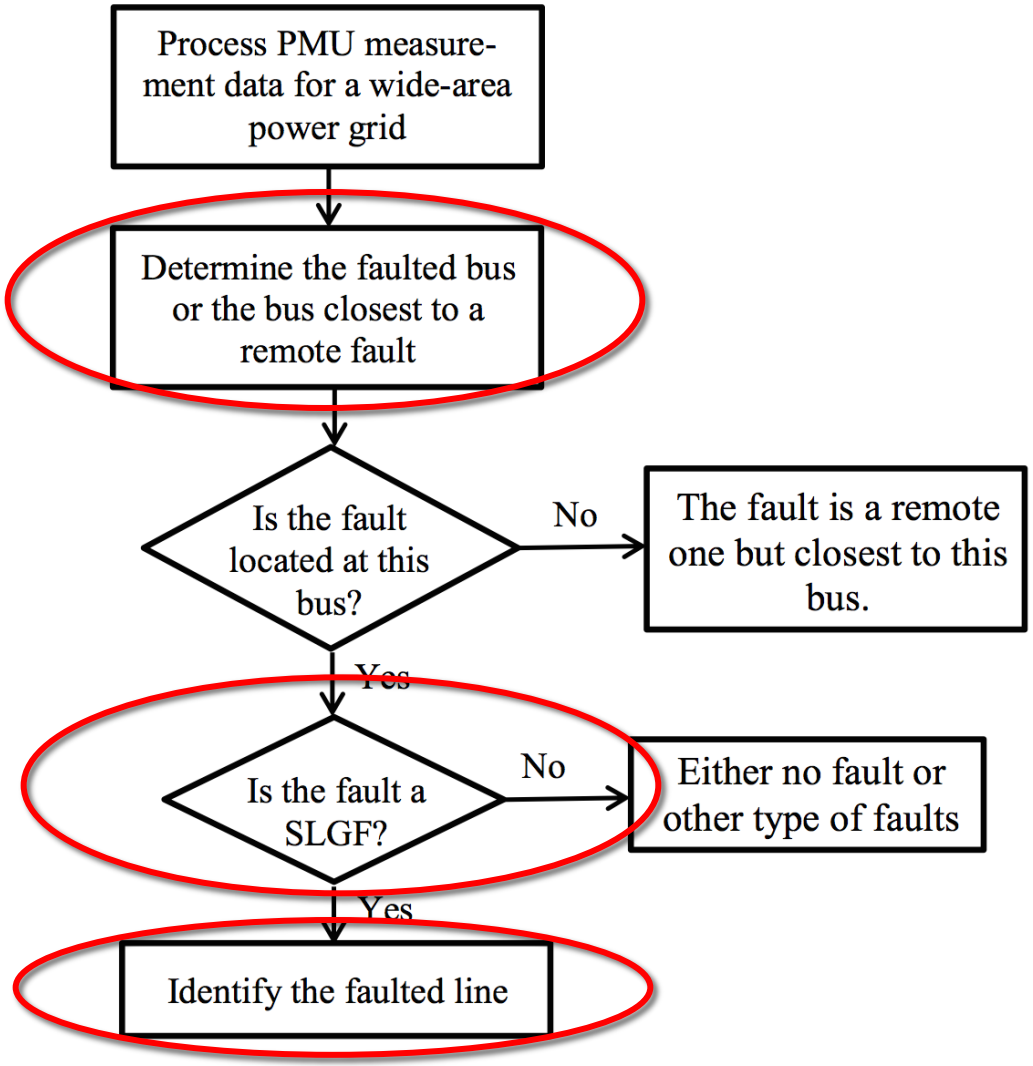
Periodic dropped measurement/signals

A Typical Single-Line-To-Ground Fault





Essential Fault Detection Process



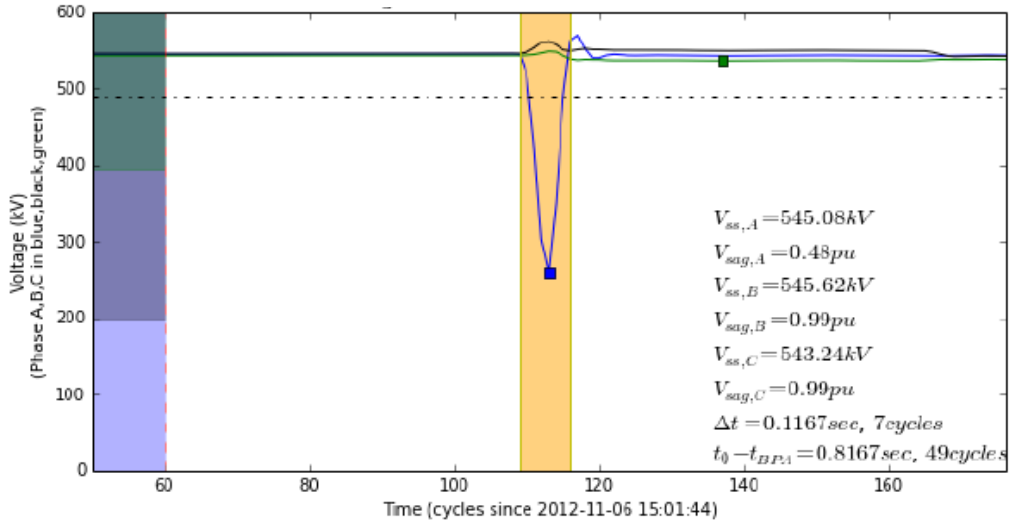
Three Building Blocks

- **Determine the bus closest to the fault**. The bus closest to the fault is found by a bus voltage deviation algorithm using the magnitude of the per-phase voltage.

- **Determine the fault type**. Whether the fault is a single-line-to-ground fault is determined based on voltage sag thresholds. These are determined by hand-built decision trees using theoretical data and measured fault data.

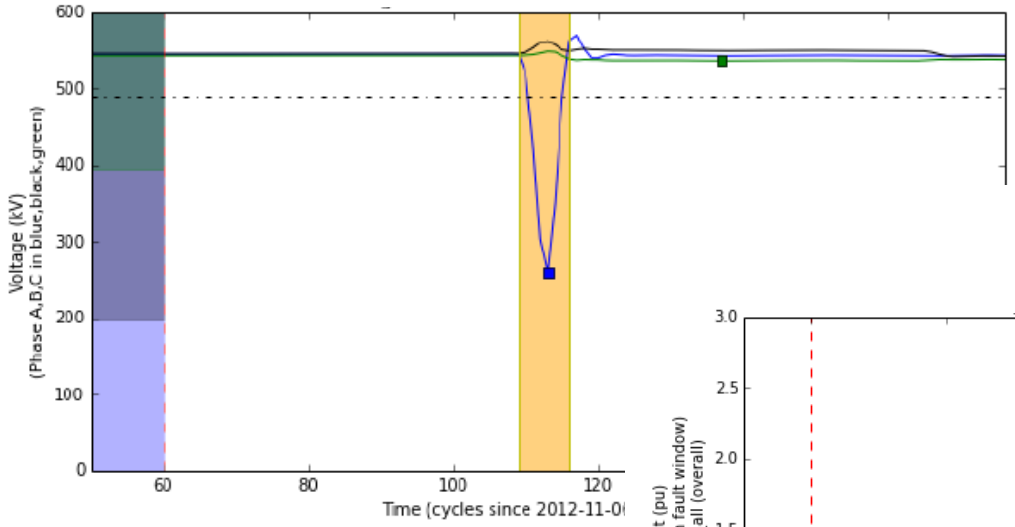
- **Determine the faulted line**. The line where is the fault is located is determined using the magnitude of positive sequence currents of lines.

Single-Line-To-Ground Faults



Nearest bus location using dominant sag

Single-Line-To-Ground Faults



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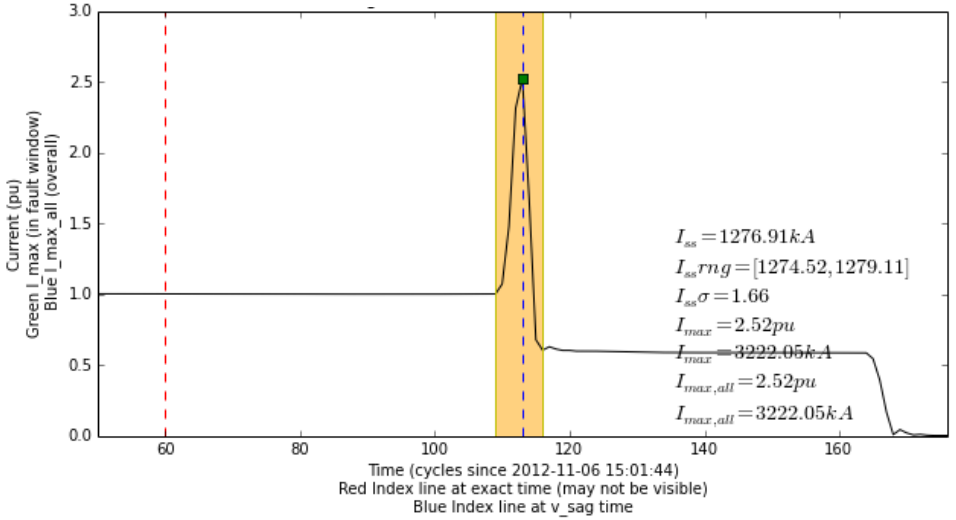
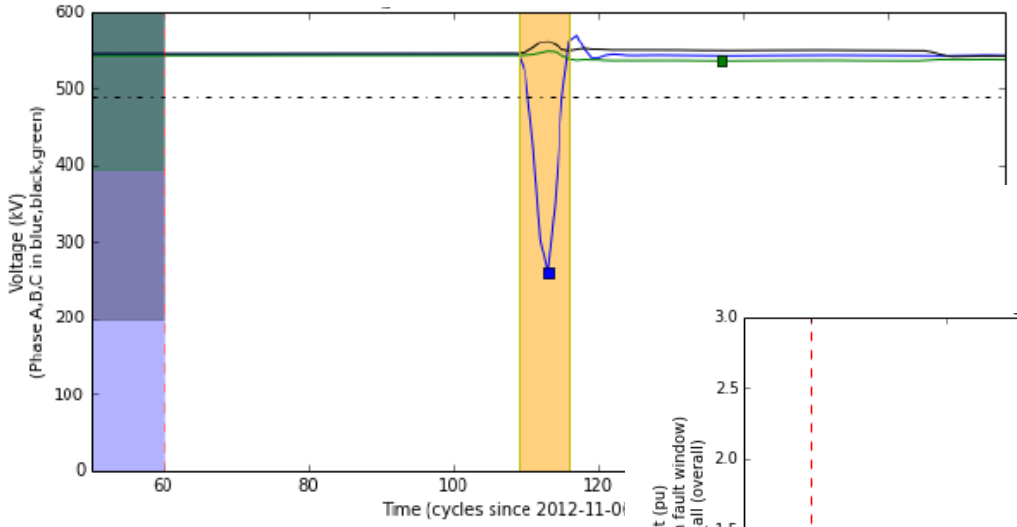
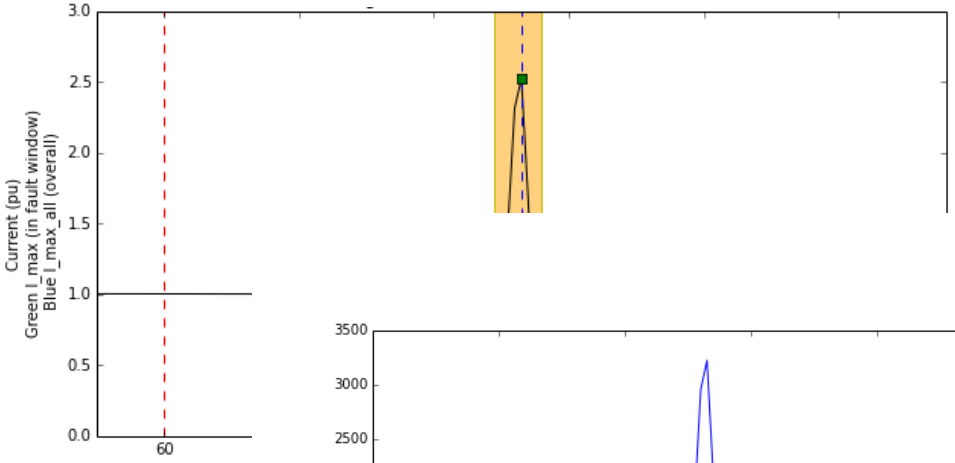


Line localization using dominant current spike

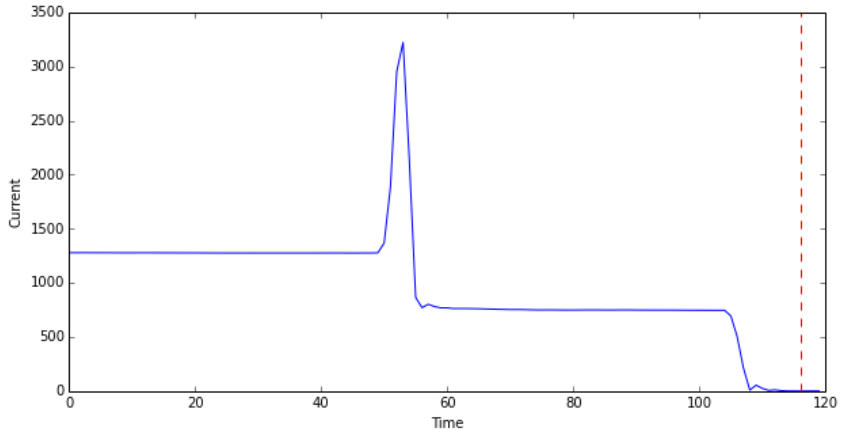
Single-Line-To-Ground Faults



Nearest bus location using dominant sag



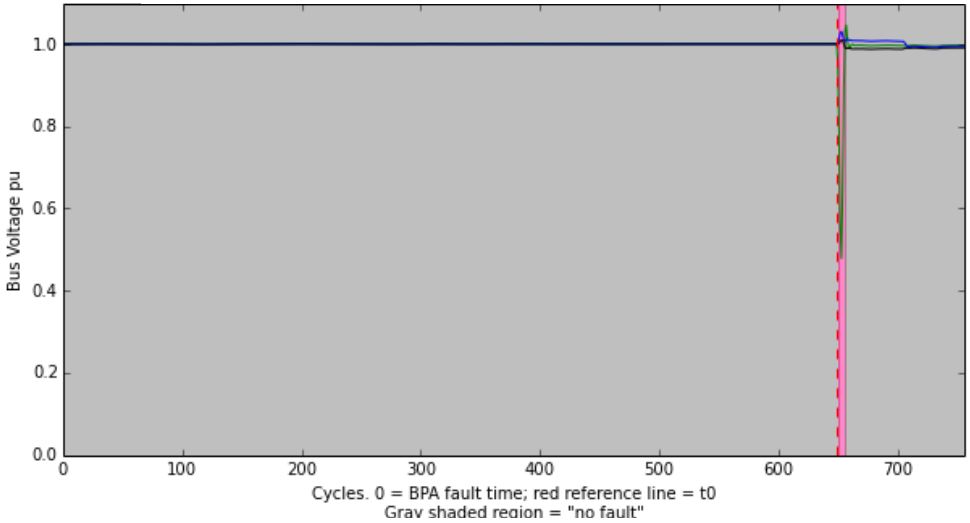
Line localization using dominant current spike and subsequent current loss



Stepwise Validation

- Identify fault given knowledge of time and location
  - (validate fault categorization) > 96% accuracy
- Identify fault location given knowledge of time
  - (validate spatial localization) > 95% accuracy

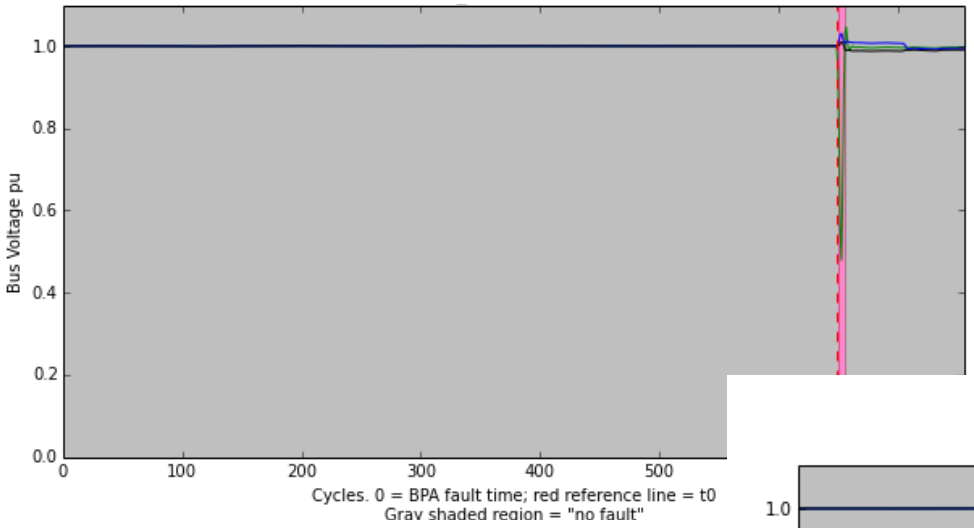
Real Time Detection



Gray region indicates *No fault* condition.

Pink region indicates *single-line to ground*

Real Time Detection



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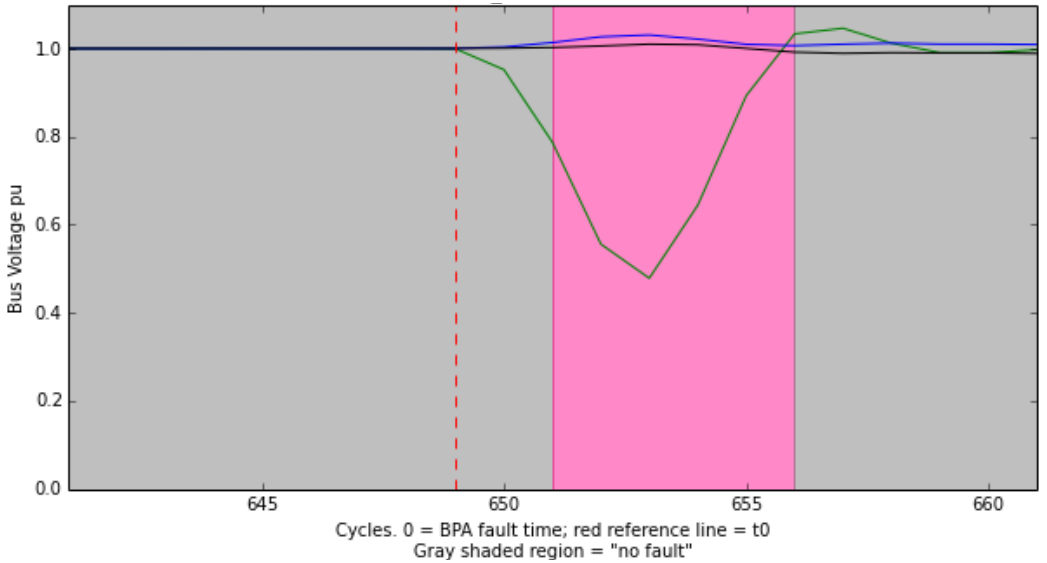

Contributions

- Provide a technique for detecting single-line-to-ground faults in a wide-area power grid.
- Issue warnings to advise the faulted bus and the faulted line.
- Properly process huge amount of PMU measurement data in a way that is useful for the development of the fault detection technique.

Future Work

- Generalize the approach to detect other types of faults, e.g., line-to-line faults, three phase faults.
- Real-time detection
- Investigate the relationship between the accuracy of the detection method and the distance to the fault
- Use machine learning techniques to derive the thresholds for voltage sags

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Questions?